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Model Millets Value Chain: Mainstreaming Millets for Nutritional Security

B. Dayakar Rao

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NABARD Research and Policy Series No. 14/2025

मॉडल मिलेट्स मूल्य श्रृंखला: पोषण सुरक्षा के लिए मिलेट्स को मुख्य धारा में लाना

Model Millets Value Chain: Mainstreaming Millets for Nutritional Security

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Chairman's Message

Academic research plays a crucial role in the process of policy formulation. The studies and analyses undertaken by researchers provide evidence based recommendations for addressing issues faced by target community. However, it is often observed that research topics are confined to specific aspect of an issue, thereby limiting their potential for comprehensive policy recommendations. Moreover, the available research reports tend to be highly technical and, therefore, less accessible to policymakers. To address these limitations, NABARD initiated a one of its kind series titled "Research and Policy" aimed at commissioning review papers that consolidate existing research findings on a given theme in a capsule form.

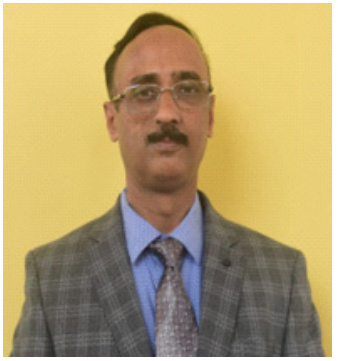
Under this series, eminent scholars from various fields of agriculture research have been invited to document research in their respective areas, highlighting key issues, policy relevance, recommendations, and suggestions for future studies.

The present paper titled "Model Millets Value Chain: Mainstreaming Millets for Nutritional Security" has been authored by Dr. B. Dayakar Rao, a distinguished expert in the field. This series will be beneficial to academicians, researchers and policymakers in addressing emerging challenges at the grassroots level.

My best wishes to the authors and the Department of Economic Analysis and Research (DEAR) of NABARD for initiating such a utilitarian and one of its kind series.

Shaji K. V.

Foreword



There exists an abundance of academic research on subjects related to agriculture and rural development, primarily dwelling in the technical domain. However, much of this research often lacks the accessibility needed to advise policy decisions effectively. It is imperative that research not only enhances our understanding of these matters but also translates into robust policies, ultimately benefitting the diverse population across the country through improved public policy and efficient services. With this intention, the much-needed series titled "Research & Policy" was initiated by DEAR. Our aspiration for this series is to encompass both the length and depth of research within a clear and concise presentation tailored for policymakers.

I am delighted to introduce the fourteenth publication in this series, titled "Model Millets Value Chain: Mainstreaming Millets for Nutritional Security", authored by Dr. B. Dayakar Rao, Ex-CEO Nutrihub and Principal Scientist (Retd), Indian Institute of Millets Research, Hyderabad. The paper analyses entire value chain, identify gaps and growth opportunities and formulate strategies to scale millet cultivation and utilisation sustainably.

We envision that this series will serve as a vital link between the academic researchers and policymakers, facilitating a more effective exchange of knowledge and ideas for the betterment of lives of people at the ground level.

Dr. Ajay K Sood
Deputy Managing Director

Preface

Indian agriculture continues to show strong performance in the current scenario, emerging as a key driver of economic growth despite growing challenges. However, there remain several structural issues that must be resolved to ensure it can sustainably support the large population depending on it. In search of solutions to address various issues and constraints amidst risks and uncertainties, agricultural research is one of the most powerful tools to eradicate extreme poverty, ensure a food-secure future, and make agriculture a sustainable livelihood. Under the guidance of Dr. Ajay K Sood, DMD, and motivated to tackle the emerging challenges facing Indian agriculture through research and effective policy interventions, the Department of Economic Analysis and Research (DEAR), an in-house research wing of NABARD, initiated the Research and Policy Series.

This series gives us a glimpse of research findings on topical themes in a capsule form thereby making it more effective and communicative to policy planners. This also distinguishes itself from opinionated articles and research available on the concerned topics of interest. For making these series a success, we approached eminent researchers in the field of agriculture and agricultural economics, as our purpose was to get researcher's heart and their experience which they gained during their long passionate innings on paper highlighting various issues, policy relevance, prescription, and suggestion for future papers on the themes of interest to NABARD.

Millets are climate-resilient crops that require minimal water and can thrive in arid conditions, making them ideal for sustainable agriculture in regions facing water scarcity. They are rich in essential nutrients, offering a nutritious alternative to conventional cereals, which is crucial for addressing malnutrition. Despite their benefits, millet cultivation was not taken up on large scale, necessitating a comprehensive analysis to identify bottlenecks and opportunities for revitalisation. Therefore, the study on the model millet value chain holds significance to understand the systemic challenges and opportunities in revitalising millet cultivation across the country. The current paper titled "Model Millets Value Chain: Mainstreaming Millets for Nutritional Security",

written by Dr. B. Dayakar Rao, Ex-CEO Nutrihub and Principal Scientist (Retd), Indian Institute of Millets Research, Hyderabad, analyses the millet value chain end-to-end, from production through processing, marketing to consumption, pinpointing critical gaps and constraints. It highlights growth opportunities, lessons from established cereal value chains, and formulates actionable strategies and an integrated framework to scale millet cultivation and utilisation sustainably.

We would like to express our sincere gratitude to Shri Shaji K. V., Chairman, NABARD, for his unwavering support and guidance in bringing this series as planned. We are grateful to the author who agreed for taking up the theme and completing the work in such a short span.

I also acknowledge the contribution of officers of DEAR, NABARD especially Smt. Balwinder Kaur, GM; Dr. Rajiv Nandan, AGM; Shri Vinay Jadhav, Assistant Manager, and others who coordinated with the authors and the editor to bring out the series as envisaged. Thanks are due to Dr. J. Dennis Rajakumar, Director, EPW Research Foundation and his team for their contribution in copy editing and bringing uniformity to the document.

Dr. Suman Kumar
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Acknowledgement

The successful completion of this policy document titled “Model Millets Value Chain: Mainstreaming Millets for Nutritional Security” has been made possible through the support, encouragement and valuable contributions of several individuals and institutions, to whom I am deeply indebted.

At the outset, I wish to express my profound gratitude to the Department of Economic Analysis and Research (DEAR), National Bank for Agriculture and Rural Development (NABARD) for their generous support and for reposing confidence in me to undertake and complete this important work. Their commitment to building and sustaining inclusive millet value chains has been a constant source of inspiration throughout the study.

I am especially thankful to Dr. Veeresh S Wali, Chief Business Manager, Nutrihub, ICAR–Indian Institute of Millets Research, for his tireless efforts, insightful guidance and steadfast involvement at every stage of this document’s development. I thank my wife, Ms. Salomi Benhur, Professor and Head of the Humanities and Social Sciences, (Creative Sciences and Entrepreneurship Department) at Mahindra University for her meticulous editing and finetuning the document, which has made the document more lucid and meaningful to the reader.

I also take this opportunity to sincerely acknowledge the contributions of the Team Nutrihub, particularly Dr. Mounika, Ms. Kiranmai, the Research Associates, and the extended team for their valuable suggestions, critical inputs, and technical support throughout the drafting process.

To all those whose support, directly or indirectly, has contributed to the successful realisation of this document, I convey my deepest appreciation and sincere thanks.

B. Dayakar Rao
Ex-CEO Nutrihub and Retd. Principal Scientist
ICAR-Indian Institute of Millets Research

Contents

(Contd....)

Contents *(Concluded)*

List of Tables

List of Figures

List of Images

Abbreviations

ABI	Agri-Business Incubation
AICRP	All India Coordinated Research Project
APEDA	Agricultural and Processed Food Products Export Development Authority
ATL	Above The Line
BIS	Bureau of Indian Standards
BTL	Below The Line
CAGR	Compound Annual Growth Rate
CFC	Common Facility Centre
CFTRI	Central Food Technological Research Institute
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council of Scientific and Industrial Research
DA & FW	Department of Agriculture & Farmers Welfare
DGFT	Director General Foreign Trade
DST	Department of Science & Technology
EDPs	Entrepreneurship Development Programmes
FAO	Food and Agriculture Organisation
FFA	Free Fatty Acids
FPOs	Farmer Producer Organisations
FSI	Food, Seed, and Industrial
FSSAI	Food Safety & Standards Authority of India
FTF-ITT	Feed the Future India Triangular Training
G20	Group of 20 Countries

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Abbreviations (*Cond....)*

GEF	Global Environment Facility
GLDC	Grain Legumes and Dryland Cereals
HPP	High Pressure Processing
HTST	High-Temperature Short-Time
IAEA	International Atomic Energy Agency
IAUC	Incremental Area Under Glucose Curve
ICAR	Indian Council of Agricultural Research
ICDS	Integrated Child Development Services
ICMR	Indian Council of Medical Research
IIMR	Indian Institute of Millets Research
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
INSIMP	Initiative for Nutritional Security through Intensive Millets Promotion
ITF	International Trade Fair on Millets and Organics
IYM	International Year of Millets
KVKs	Krishi Vigyan Kendra
MPLS	Maximum Permissible Limits
MEGP	Mapping and Exchange of Good Practices
MoAFW	Ministry of Agriculture and Farmers Welfare
MoCI	Ministry of Commerce and Industries
MoFPI	Ministry of Food Processing Industries
MoRD	Ministry of Rural Development

Contd....

Abbreviations (*Cond....)*

MoU	Memorandum of Understanding
MWCD	Ministry of Women and Child Development
NABARD	National Bank for Agriculture and Rural Development
NAFED	National Agricultural Cooperative Marketing Federation of India
NCDC	National Cooperative Development Corporation
NEST	Nutri-cereals Entrepreneurship & Startup Training
NGRAIN	Growing & Rewarding Agripreneurship in Nutriceareals
NIFTEM-K	National Institute of Food Technology, Entrepreneurship and Management-Kundli
NIFTEM-T	National Institute of Food Technology, Entrepreneurship and Management-Thanjavur
NIN	National Institute of Nutrition
NITI	National Institution for Transforming India
PDS	Public Distribution System
PIB	Press Information Bureau
PL	Pulsed Light
PPP	Public-Private-Partnership
RABI	RAFTAAR-ABI
RAFTAAR	Remunerative Approaches for Agriculture and Allied Sector Rejuvenation
RTC	Ready To Cook
RTE	Ready To Eat
RKVY	Rashtriya Krishi Vikas Yojana
SAUs	State Agriculture Universities

Contd....

Abbreviations (*Concluded)*

SFAC	Small Farmers' Agri-Business Consortium
SHGs	Self-Help Groups
SMIL	Sorghum and Millet Innovation Lab
SOPs	Standard Operating Procedures
SSTC	South-South & Triangular Cooperation
TBI	Technology Business Incubator
TEDP	Entrepreneurship Development Technology Programmes
TNAU	Tamil Nadu Agriculture University
USA	United States of America
USAID	United States Agency for International Development
WCD	Women and Child Development
WFP	World Food Programme
WHO	World Health Organisation

Executive Summary

Millets, also known as nutri-cereals, are traditional staple foods grown primarily in dryland regions. These crops, including varieties like sorghum, pearl millet and finger millet, are highly nutritious, and they play a crucial role in ensuring food security. Originating from Asia and Africa, millets have adapted to various climates, and are now cultivated globally, particularly in India, which is the world's largest millet producer.

Millets offer multiple benefits. They are smart foods; good for human health due to their high nutritional contents like protein, fiber and essential minerals. They are also beneficial for farmers, as they are resilient, require minimal water, and can be grown on marginal lands. Environmentally, millets are sustainable, requiring less water and energy for cultivation, and are carbon neutral crops. The global market for millets is growing driven by increased consumer demand for healthy and sustainable food options. India is positioned as a leader in this market with significant potential for both domestic consumption and export.

Key challenges in the millet value chain include lower productivity due to cultivation on marginal lands, outdated farming practices and inefficient processing technologies. The study draws lessons from the value chains of rice, wheat and maize, which have benefitted from advanced technologies, policy support and market-driven demand.

This study focuses on modelling the millet value chain to mainstream millets beyond 2023 within India's agricultural landscape. It addresses the entire value chain from production to consumption, identifying gaps, growth opportunities and proposing actionable steps for sustainable and scalable millet production and consumption.

An integrated approach is presented to promote millets in India and globally to overcome the global decline in cultivation. Productivity has improved, especially in India, where cultivation peaked in the 1980s but has since decreased. The Indian Council of Agricultural Research-Indian Institute of Millets Research (ICAR-IIMR) has played a pivotal role in revitalising the millet sector through innovative interventions and by developing value-added products.

The ICAR-IIMR's efforts have led to significant advancements in millet production, processing and commercialisation. This includes the establishment of farmer producer organizations (FPOs) to improve farmers' access to markets, development of value-added products and commercial technologies through partnerships with startups and industries. Awareness campaigns and promotional activities have also been conducted to educate consumers about the nutritional benefits of millets.

The study highlights the importance of a multi-stakeholder approach to modelling of the millet value chain, involving government agencies, private sector players and international organisations. Future strategies include increasing millet cultivation in non-traditional areas, improving processing technologies, linking startups with markets and repositioning millets in global markets.

Model Millets Value Chain: Mainstreaming Millets for Nutritional Security

1. Introduction

Millets, often referred to as nutri-cereals, are traditional staple foods in the dry land regions of the country. Millets are highly nutritious cereals, and they contribute substantially to food and nutritional security. Millets are a group of cereal food grain crops, which are small seeded and adapted to cultivation over a range of tropical and subtropical climates, and can be grown with very low inputs. The major millet crops are *jowar* or sorghum *(Sorghum bicolor)*, *bajra* or pearl millet *(Pennisetum typhoides)* and mandua/*ragi* or finger millet *(Eleusine coracana)*, and the small millets are kangni or foxtail millet *(Setaria italica)*, kutki or little millet *(Panicum miliare)*, kodo millet *(Paspalum scrobiculatum)*, jhangora or barnyard millet *(Echinochloa frumentacea)*, cheena or proso millet *(Panicum miliaceum)* and korale or brown top millet *(Brachiaria ramosa)*.

Originated in Asia and Africa, the millet crops were domesticated by the local populations, and their cultivation has spread to the other regions of the world. Further domestication in other regions gave rise to the secondary regions of diversity and adaptation and different use options.

1.1 Origin of Millets

- **Sorghum:** Sorghum *(Sorghum bicolor)*, scientifically known as C4 plant, is one of the most energy efficient crops that uses solar energy and water to produce food and biomass. In the grain form, it is used mainly for food, prepared in the form of flat breads and porridges of different kinds. Sorghum originated in north eastern Africa, with domestication having taken place there around 5,000–8,000 years ago. The secondary centre of origin of sorghum is the Indian subcontinent, which has evidences for early cereal cultivation dating back about 4,500 years. Sorghum stover is a vital source of fodder for livestock. Over half a billion people rely on sorghum as a dietary mainstay and, given its diverse uses, as an important source of income.

- **Pearl Millet:** Pearl millet *(Pennisetum glaucum)* is the most widely cultivated cereal in India after rice and wheat. Pearl millet originated in the West Africa.

The domestication of pearl millet occurred in northern central Sahelian Africa around 4,500 BC. More than 90 million poor people depend on pearl millet for food and income. They generally live in the drier parts of Africa and Asia - places where most other crops cannot grow, and local farm households have nowhere else to turn for food security.

- **Finger Millet:** Finger millet *(Eleusine coracana)* is an important primary food especially for the rural populations of Southern India and East and Central Africa. Finger millet seems to have originated in the hills of western Tanzania or Ethiopian highlands. It is a domesticated cereal of African origin which spread in prehistory to Asia. The Asia upland races, which are especially widespread in the Himalayas from India to Nepal and southern China, appear to be a secondary adaptation. The grain is very nutritious, and has excellent malting properties.

Types of Millets (Major Millets & Minor Millets)

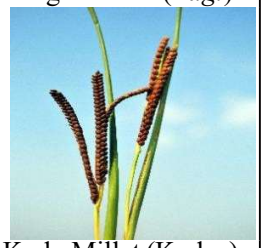
Sorghum (*Jowar*)

Pearl Millet (*Bajra*)

Finger Millet (*Ragi*)

Foxtail Millet (Kangni)

Little Millet (Kutki)



Kodo Millet (Koden)

Browntop Millet

Barnyard Millet (Sanwa)

Proso Millet (Barri)

Image Credits: ICAR-IIMR

- **Barnyard Millet:** Barnyard millet *(Echinochloa colona)* is cultivated on marginal lands, where rice and other crops will not grow well. It is grown for both grain and fodder in India, especially in the hilly tracts of Uttarakhand, eastern Asia and parts of Africa. It has been a valuable forage crop in the eastern United States of America (USA). There is not much information on the origin of barnyard millets. General consensus is that they originated in central Asia; *echinochola crus-galli* was domesticated in Japan, China and Korea, whereas *echinochloa frumentacea* was domesticated in India. Barnyard millet is the fastest growing of all millets with some varieties capable of producing a crop in just six weeks.

- **Proso Millet:** Proso millet *(Panicum milaceum)* is a short season crop cultivated in drier regions of Asia, Africa, Europe, Australia and North America. The grain after hulling makes a nutritious and palatable cereal for unleavened bread or cooked. Proso millet or common millet is the true millet of historical significance and it is one of the oldest human foods and believed to be the first domesticated cereal grain. Most of the evidences consider proso millet to be of central or eastern Asiatic origin, since the diversity increases towards Mongolia, China and eastern Asia. Yellow River valley of China has been suggested to be the origin. Proso millet is well adapted to many soil and climatic conditions. Being a short season crop with a low water requirement, it grows further north than the other millets and adapts well to plateau conditions and high elevations.

- **Foxtail Millet:** Foxtail millet *(Setaria italica)* grains are very similar to paddy rice in grain structure. They contain an outer husk, which needs to be removed in order to be used. Foxtail millet was domesticated in China more than 8,000 years ago, contributing greatly to the development of Chinese civilisation and remained a staple cereal in arid and semi-arid regions. Foxtail millet is fairly tolerant of drought; it can escape some droughts because of early maturity. Due to its quick growth, it can be used as a short-term catch crop. It is adapted to a wide range of elevations, soils and temperatures, but it cannot tolerate water logging.

- **Little Millet:** Little millet *(Panicum sumatrense)* is similar to proso millet in appearance but is generally shorter. It has smaller panicles and seeds, and is grown on a limited scale voluntarily or with minimum care on poor lands. The origin of the little millet crop is not well documented except for the probable Indian origin, since it is endemic to India and has a name in all vernacular languages of India.

This millet was cultivated or naturalised throughout India and Sri Lanka, and cultivated in other neighbouring countries. Little millet is a reliable, fast growing crop that is early maturing and resistant to adverse agro-climatic conditions.

- **Kodo Millet:** Kodo millet *(Paspalum scrobicultum)* is an annual tufted grass that grows up to 90 centimeter (cm) high. The grain is enclosed in hard, corneous and persistent husks that are difficult to remove. Kodo millet, also known as cow grass, rice grass, ditch millet, native paspalum or Indian crown grass, originated in tropical Africa, and it is estimated to have been domesticated in India 3,000 years ago. *Paspalum scrobiculatum var. scrobiculatum* is grown in India as an important crop, while *Paspalum scrobiculatum var. commersonii* is the wild variety indigenous to Africa. Often, it grows as a weed in rice fields. Many farmers do not mind it, because it can be harvested as an alternative crop if the primary crop fails. Kodo millet has around 11% protein, and the nutritional value of the protein has been found to be slightly better than that of foxtail millet, but comparable to that of other small millets.

- **Brown Top Millet:** Brown top millet *(Urochloa ramose)*, a native of India, has relatively limited cultivation in some parts of Karnataka and Andhra Pradesh, though its occurrence as a weed is noted in all states of India. The domestication of brown top millet probably occurred in south India and in the Deccan, and it spread during prehistory outward to other parts of India. Evidences suggest that this crop, along with other south Indian crops, developed from indigenous wild populations around the beginning of the third millennium BC. It can be grown even in fertile sandy loam soils. It matures in 60-80 days, and is the most inexpensive crop to grow. It does not need weeding or suffer from any serious pests and diseases.

1.2 Millets as Smart Foods

The smart food campaign of International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and Indian Council of Agricultural Research-Indian Institute of Millets Research (ICAR-IIMR) highlights the nutritional, environmental and economic benefits of millets, particularly for smallholder farmers.

1.2.1 Consumption Benefits

Millets offer exceptional nutritional value, making them an excellent choice for human consumption. Their protein content ranges from 10%-12%, with foxtail millet

containing an impressive 12.3% protein, surpassing both wheat and rice. This high protein content makes millets a valuable food source, especially in regions where protein malnutrition is a concern.

The dietary fiber content in millets (10%-12%) is also superior to many staple cereals. Their high fiber content aids in digestion and promotes feelings of fullness, and can help in managing weight. It also contributes to better gut health, and may reduce the risk of colon cancer.

Millets are rich in essential minerals. For instance, finger millet (*ragi*) contains an astounding 364 milli gram (mg) of calcium per 100 gram (g), which is 10 times higher than wheat or rice. This makes it an excellent source of calcium, particularly important for bone health. Pearl millet (*Bajra*) and barnyard millet are high in iron (6.42 mg/100g and 5.0 mg/100g, respectively), addressing iron deficiency issues.

The low to medium glycemic index of millets makes them an ideal food for managing diabetes. Unlike high glycemic index foods that cause rapid spikes in blood sugar, millets release glucose slowly into the bloodstream, helping to maintain stable blood sugar levels.

Millets are naturally gluten-free, making them safe for people with celiac disease or gluten sensitivity. This characteristic allows these individuals to enjoy a diverse and nutritious diet without compromising their health.

1.2.2 Benefits to Farmers

The short growing cycle of millets (60-90 days) compared to fine cereals (100-140 days) allows for more efficient land use through crop rotation. This quick turnaround can potentially increase overall farm productivity and income.

Millets are incredibly resilient crops. They can withstand extreme temperatures (up to 64° C) and thrive in drought conditions where other crops might fail. This resilience makes them a secure crop choice for farmers in regions with unpredictable weather patterns or limited water resources.

These crops are also highly responsive to improved farming conditions. With the application of additional inputs and better agricultural practices, millet yields can increase up to threefold. This responsiveness provides farmers with the

opportunity to significantly boost their productivity and income with relatively modest investments.

Millets' ability to grow in harsh conditions means they can be cultivated on marginal lands that might otherwise be unproductive. This characteristic allows farmers to make use of land that is not suitable for other crops, potentially increasing their total cultivable area and overall farm output.

1.2.3 Benefits for the Planet

Water efficiency is one of the most significant environmental benefits of millets. They require only 300-400 mm of water, compared to the 1,400-1,500 mm needed for rice cultivation. This makes millets an excellent choice for water scarce regions and helps conserve this precious resource.

Millets are considered carbon neutral crops. They absorb carbon dioxide from the atmosphere equivalent to what they emit during their production cycle (0.1-0.2 CO_2 equivalent kilogram (kg) per kg of production). In comparison, rice production emits 0.4 CO_2 equivalent kg per kg, and wheat 0.35 CO_2 equivalent kg per kg. This carbon neutrality contributes to mitigating climate change effects.

The energy efficiency of millets is another environmental advantage. They require less fertilizer and irrigation, consuming only 0.48-0.71 kilowatt hour (kWh) of energy per kg of production, compared to 1.05 kWh per kg for rice. This lower energy requirement translates to reduced fossil fuel consumption and lower greenhouse gas emissions.

Millets' ability to grow in arid regions helps to combat desertification and maintain biodiversity in challenging environments. Their cultivation can help preserve soil health and prevent land degradation in areas prone to these issues.

1.2.4 Advantages/Opportunities for Business

The global millets market is experiencing robust growth. Valued at US$ 14.22 billion in 2023, it is projected to reach US$ 23.83 billion by 2033. This growth trajectory indicates increasing consumer demand and market potential for millet-based products.

India plays a dominant role in the global millet market, producing over 40% of the world's millets. The Indian millet market was valued at US$ 5.05 billion in 2022, highlighting the scale of domestic consumption and production.

Major food and beverage companies are capitalising on the millet trend and expanding their millet-based product portfolios. This includes a wide range of products

from biscuits and packaged foods to millet-based beers, indicating the versatility of millets in food processing.

The export potential for millets is substantial. India is aiming to tap into a US$ 2 billion export opportunity by promoting millet-based products. This presents significant opportunities for businesses involved in millet production, processing and export.

Millets offer a unique selling proposition as healthy and environmentally friendly alternatives to water intensive crops like wheat and rice. This aligns with growing consumer trend towards health conscious and sustainable food choices, potentially driving up demand and premium pricing for millet-based products.

1.3 Millet Production: Global and Indian Perspective

1.3.1 Global Scenario of Millet Production

Millets are presently cultivated in 131 nations across approximately 78 million hectares, with sorghum and pearl millet comprising more than 90% of the global total. India, the world's largest millet cultivator, contributes 19% of the global cultivated area and produces 20% of the world's millet output. In the Asian context, India accounts for 85% of millet cultivated area and 80% of millet production (FAO's *FAOSTAT*, 2022). The International Year of Millets (IYM) 2023 has had a significant impact on the cultivation, consumption and market for millets in India and around the world. Millets featured prominently at G20 events to raise awareness and encourage their consumption. The Government of India is actively promoting millets through multi-stakeholder engagement, involving ministries, states and Indian embassies globally. With the global millets market projected to reach UD$14.14 billion by 2028, India is seeking a significant share. As a top exporter, India's key markets are in the Middle East, Nepal and Bangladesh.

The global cultivation of millets has shown interesting regional variations from 2017 to 2022. Africa consistently remains the largest millet growing region, with the cultivated areas fluctuating between 47 million hectares and 50 million hectares. Despite some year-to-year variations, Africa's millet cultivation has remained relatively stable, with a slight increase observed in 2022 over 2021. Similarly, Africa has consistently been the largest millet producing region, with production fluctuating: though

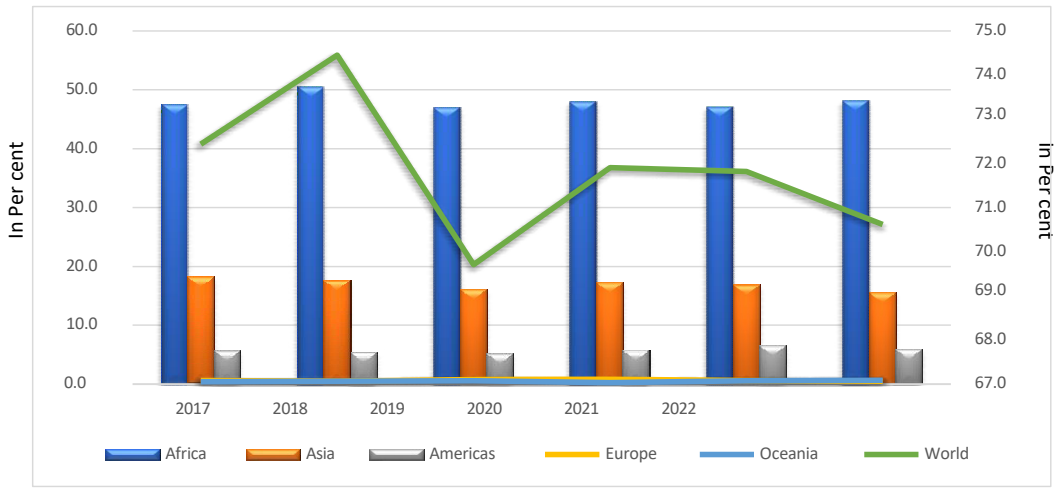
production peaked at 45.76 million tonnes in 2018, it declined to 38.03 million tonnes in 2021 and subsequently recovered to 44.17 million tonnes in 2022. This volatility in African millet cultivation may be attributed to factors such as changing weather patterns, agricultural policies and shifts in farmers' preferences.

Asia, the second-largest millet producing region, has experienced a notable decline in the cultivated area from 18.21 million hectares in 2017 to 15.47 million hectares in 2022. This trend suggests a shift in agricultural priorities or challenges to millet cultivation in the Asian continent. Millet production in Asia showed somewhat a rising trend from 23.07 million tonnes in 2017 to 26.30 million tonnes in 2021, however, it dipped to 23.85 million tonnes in 2022.

Americas hold the third position in millet cultivation, with minor fluctuations. The area under millet cultivation in America reached the lowest level at 5.21 million hectares in 2019, but peaked at 6.60 million hectares in 2021. This indicates a potential renewed interest in millet cultivation in recent years. Millet production in America gradually declined from 20.43 million tonnes in 2017 to 19.21 million tonnes in 2019, but rose steeply to 23.95 million tonnes in 2021. However, 2022 witnessed dramatic drop in millet production in the region to 16.60 million tonnes. This volatility might indicate changing agricultural priorities or fluctuating market demand in the region.

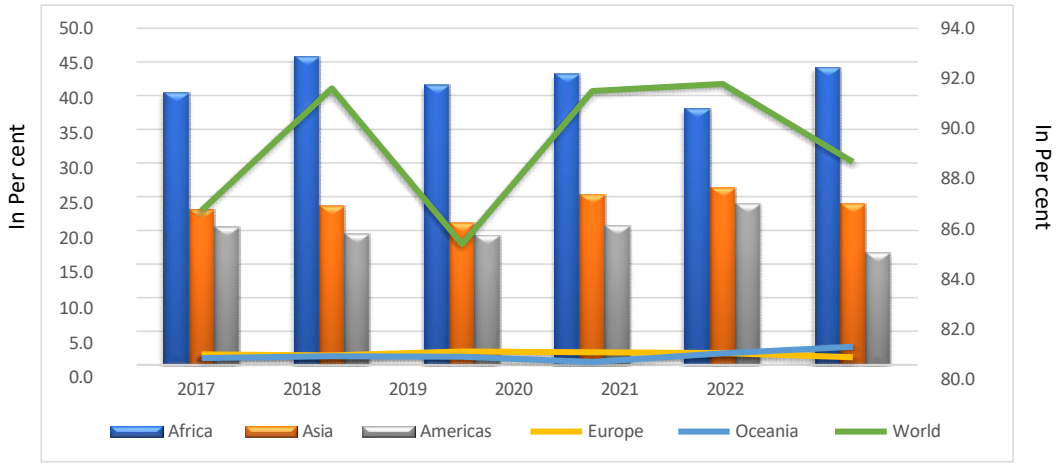
Europe and Oceania, while being smaller contributors to global millet production, show distinct trends. Europe's millet cultivation area fluctuated between 0.49 million hectares and 0.83 million hectares, peaking in 2020 but showing a decline in the subsequent two years. Oceania, despite being the smallest millet growing region, witnessed its area under millet cultivation expanding from 0.41 million hectares in 2017 to 0.66 million hectares in 2022, with a notable exception of a significant drop in 2020. In case of production, Europe showed an increase from 1.54 million tonnes in 2017 to a peak of 2 million tonnes in 2019. However, the subsequent years saw a decline, with 2022 recording the lowest production at 1.14 million tonnes. Such a trend might reflect changing European agricultural policies or shifting consumer preferences. In contrast, Oceania recorded a rise in millet production from 1.04 million tonnes in 2017 to 2.69 million tonnes in 2022, although the production experienced a significant drop to 0.44 million tonnes in 2020 due to severe drought conditions. This might indicate new agricultural initiatives or changing climatic conditions favouring millet cultivation in the region.

Figure 1: Region-wise Trends in Area under Millet Cultivation, 2017-2022



Source: Author's estimates based on data extracted from FAO's *FASTAT* in 2022.

Figure 2: Region-wise Trends in Millet Production, 2017-2022



Source: Same as Figure 1

The global trend in millet cultivation shows a slight overall decline during this period. The area under millet cultivation at the global level peaked at 74.45 million hectares in 2018, dropped to 69.71 million hectares in 2019, but went up to 70.62 million hectares in 2022. The millet production showed an increase from 86.43 million tonnes in 2017 to peak at 91.69 million tonnes in 2021 but then dropped to 88.44 million tonnes in 2022. This global trend, combined with regional variations, suggests a complex interplay of factors affecting millet cultivation worldwide, such as

changing agricultural practices, climate conditions, and potentially shifting dietary preferences or economic considerations.

1.3.2 Millet Production in India

India is the largest producer of millets in the world. It accounts for 20% of the global production in 2022. Millets are cultivated in 21 states, and some of the major millet producing states are Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Telangana, Uttarakhand, Jharkhand, Madhya Pradesh, Haryana and Gujarat. Amongst these, Rajasthan and Uttar Pradesh are the major producers of pearl millet, but their yield are lower compared to the national average. Maharashtra, Karnataka and Rajasthan are top producers of *jowar* but not the most productive. Karnataka is the leader in *ragi* production. Small millets have more cultivation area compared to *ragi*. There is much scope to improve productivity in almost all the states (Sreekala *et. al.,* 2023).

In India, millets are cultivated in an area of 12.93 million hectares, producing 16.76 million tonnes with a yield of 1,349 kg/ha. Pearl millet has the highest area under cultivation at 7.23 million hectares. Sorghum is cultivated in the *Kharif* season in about 1.51 million hectares. The area under *Rabi* season (2.6 million hectares) is higher than *Kharif* season. *Ragi* and small millets are cultivated in about 1.15 million hectares and 0.45 million hectares, respectively (Table 1).

1.3.3 Sorghum

Sorghum is a major crop grown in India throughout the year. There are two main planting seasons Kharif or monsoon season (accounting for 37% of cultivation) and

Table 1: Area, Production and Productivity of Millets in India, 2024

Crop	Area (million hectares)	Production (million tons)	Productivity (kg/hectare)
Sorghum (Kharif)	1.51	1.65	1,097
Sorghum (Rabi)	2.60	2.80	1,082
Bajra	7.23	10.18	1,408
Ragi	1.15	1.74	1,524
Small Millets	0.45	0.38	849
Total	12.94	16.75	1,349

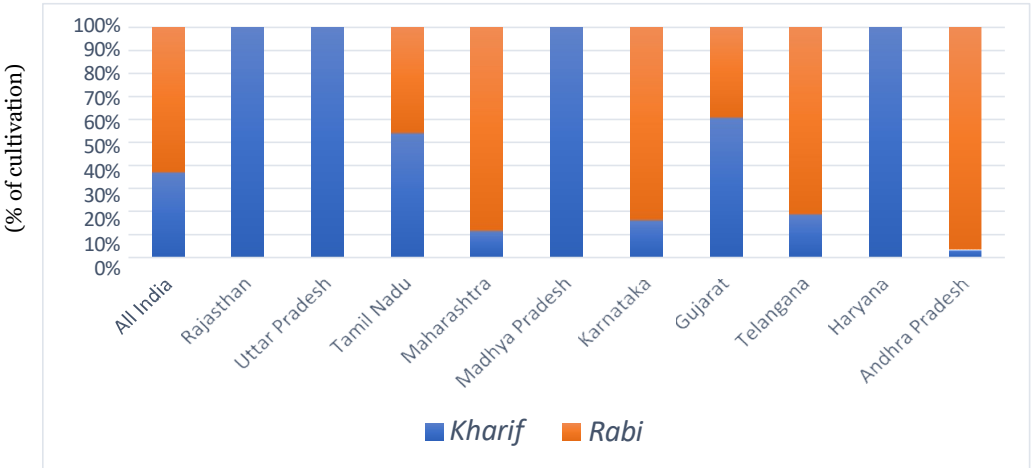
Source: Author's estimates based on data obtained from Directorate of Economics and Statistics, Government of India.

Rabi or winter season (accounting for the remaining 63% of cultivation). The total area under sorghum cultivation is around 4.16 million hectares. Sorghum cultivation is spread across many states, with Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Gujarat, Rajasthan, Uttar Pradesh and Haryana being the top producers (Figures 3 and 4). Sorghum production in the country shows interesting seasonal variations. During the Rabi (winter) season, Maharashtra and Karnataka account for a whopping 55% of the cultivated area and the total sorghum produced. However, the story is different for the Kharif (monsoon) season: Maharashtra, Karnataka and Rajasthan collectively hold the lead and contribute around 50% of the area and production.

However, the sorghum cultivation patterns have undergone a shift over the past decade. The Kharif season has seen a dramatic decline in area to nearly a half of the area in 2011-12. This decline is particularly sharp in Maharashtra, Madhya Pradesh and Karnataka, where cultivation has shrunk by almost 70%. Interestingly, Rajasthan and Tamil Nadu have bucked the trend, increasing area under sorghum in kharif season by 40%.

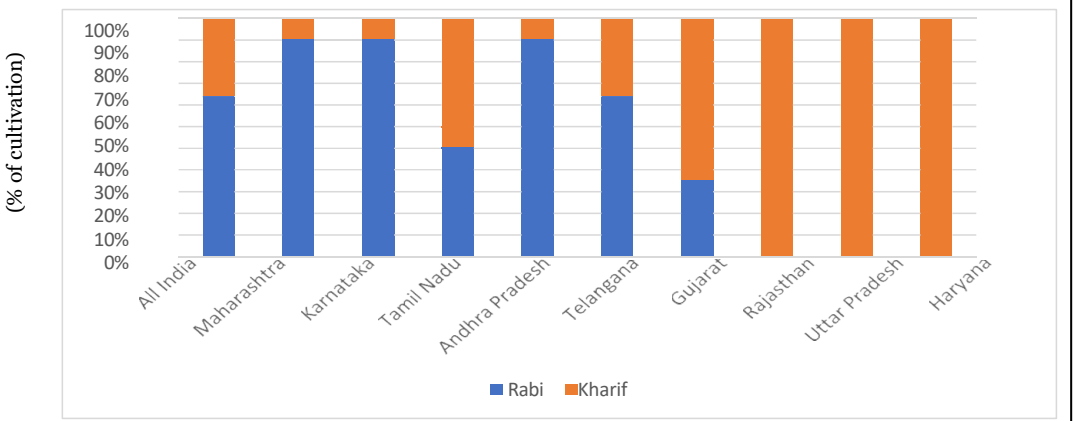
The Rabi season has also witnessed many changes. Gujarat has seen a staggering 75% decrease in its Rabi sorghum area. Maharashtra and Karnataka also recorded 40%-50% reduction. However, Tamil Nadu has emerged as a new player, rapidly

Figure 3: Production of Sorghum in India (Top 10 States), 2024



Source: Author's estimates based on data obtained from Directorate of Economics and Statistics, Government of India.

Figure 4: Area under Sorghum Cultivation in India (Top 10 States), 2024



Source: Same as Figure 3

expanding its Rabi sorghum cultivation. Kerala has joined the league recently by starting to cultivate Rabi sorghum.

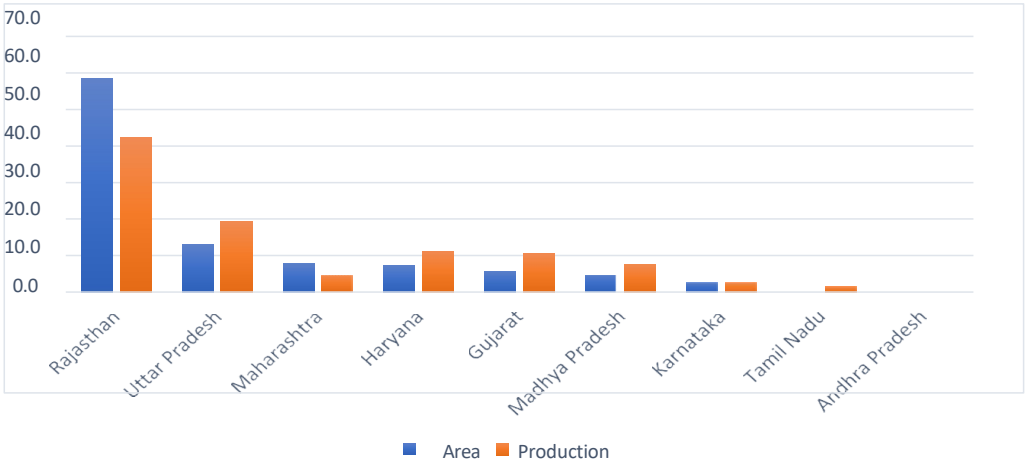
These trends suggest a dynamic shift in sorghum cultivation. While traditional areas are scaling back, new regions are stepping up. The decline in some areas can be attributed to competition from other crops. During Kharif season, farmers might be lured by paddy, sugarcane, soybean, cotton, maize and small millets. Similarly, Rabi season faces competition from sugarcane, soybean, chickpea and wheat. These alternatives might offer better financial returns, and they are more suitable for volatile markets, thereby, influencing farmers' decisions.

1.3.4 Bajra

Bajra, being a rainfed crop traditionally cultivated across India during the *Kharif* season, thrives in the monsoon climate. While *bajra* has a national presence, six states – Rajasthan, Uttar Pradesh, Maharashtra, Haryana, Gujarat, and Madhya Pradesh – reign supreme. Collectively, these states contribute considerably (92%) to the total area under *bajra* cultivation. This concentrated production pattern suggests that these states, primarily located in the northern, western and central regions, are the traditional regions for *bajra* cultivation in the country.

Interestingly some states like Rajasthan, Gujarat, Karnataka and Tamil Nadu are venturing into summer cultivation, showcasing its potential for multi-seasonality cropping. Rajasthan, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Maharashtra

Figure 5: Area and Production of Bajra in India (Top 10 States), 2024



Source: Same as Figure 3.

and Karnataka are the powerhouses for *bajra* production, contributing to over 97% of the national output. The difference between the top states in area and production hints at variations in productivity across regions (Figure 5).

However, the recent trends have raised concerns. Bajra cultivation area has shrunk by 22% nation-wide over the past decade. Gujarat and Karnataka have seen the steepest decline, with nearly a 50% reduction in area. Maharashtra and Rajasthan have faced decline of 20%-25% in area. This shift away from bajra in traditional areas can be attributed to competition from crops like cotton, maize and sugarcane. These crops offer better market prospects, economic returns or benefit from changing agricultural policies.

Despite the overall decline in area, there is a silver lining. Some states like Madhya Pradesh, Tamil Nadu and Uttar Pradesh have managed to increase production from 19% to a staggering 152% as compared to 2011-12. This rise in production despite a decrease in area suggests improvements in bajra cultivation techniques or a shift towards more productive bajra growing regions within these states.

1.3.5 Ragi

Ragi, also known as finger millet, is a significant player in India's diverse agriculture landscape, particularly in specific regions. This grain thrives during the monsoon season, showcased by its primary cultivation during Kharif. This single season dependence highlights ragi's remarkable adaptation to and reliance on monsoon rains.

Interestingly, ragi cultivation is not scattered uniformly across the country. Five states - Karnataka, Tamil Nadu, Uttarakhand, Maharashtra and Odisha - reign supreme, contributing over 92% to the total ragi cultivated area.

Ragi cultivation in India reveals an interesting story of regional variations. While Karnataka, a major producer, has seen a 25% increase in cultivation area, ragi production in the state has dipped by 10%. This suggests challenges like declining productivity or unfavourable growing conditions. Conversely, states like Odisha and Jharkhand are experiencing a boom, with ragi production increase ranging from 40% to a staggering 110%. Jharkhand's case is particularly interesting as it has also expanded its ragi cultivation area significantly.

Several factors influence these trends. Competition from crops like soybean, cotton, paddy, maize and small millets plays a role. These crops might offer better market prospects and higher economic returns, or are easier to cultivate in certain regions. Additionally, economic factors like market prices and established supply chains, climate shifts impacting suitability for ragi, and changing food habits may influence farmer decisions.

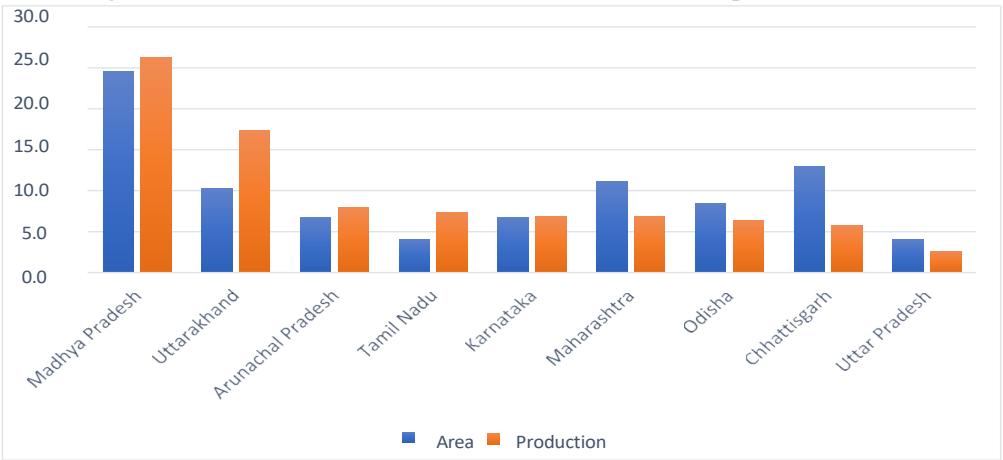
While some traditional areas face decline, others are flourishing. The dominance of Karnataka and Tamil Nadu highlights the crop's significance in the south. States like Jharkhand show promise for future growth. However, concerns remain about declining production in the traditional areas and challenges faced by ragi cultivation overall. Targeted interventions are crucial. Research, supportive policies and efforts to improve ragi productivity, market linkages and consumption could help to sustain and revitalise this valuable crop across the country. By addressing these challenges and capitalising on ragi's strengths, India can foster its role in food security and agricultural diversity. Government policies, research efforts and even nutritional awareness could play an important role in promoting the crop. Investment in improved ragi varieties or cultivation practices, like those potentially seen in Jharkhand and Odisha, could enhance production. Similarly, a growing understanding of ragi's nutritional value might prove helpful in encouraging cultivation in some areas.

1.3.6 Small Millets

Unlike sorghum and other millets, small millets in India are predominantly a Kharif (monsoon) season crop. This widespread single season cultivation highlights their remarkable adaptability to the diverse agro-climatic conditions that prevail

across the country during the monsoon months. Interestingly, even though small millets are grown throughout India, seven states take the lead: Madhya Pradesh, Maharashtra, Uttarakhand, Karnataka, Arunachal Pradesh, Odisha and Uttar Pradesh. These states account for 87.7% of the total area dedicated to small millets and a staggering 88.9% of the total production (Figure 6).

Figure 6: Area and Production of Small Millets in India (Top 10 States), 2024



Source: Same as Figure 3

Small millets in India are experiencing a geographical shift in cultivation. While it is traditionally a Kharif crop which is grown across the country, some states like Chhattisgarh, Madhya Pradesh, Uttarakhand and Tamil Nadu have seen significant declines in area (20%-65%) and production (especially Tamil Nadu). This decrease can be attributed to competition from crops like soybean, cotton, paddy and maize, which might offer better market prospects or be easier to cultivate.

On the other hand, states like Karnataka, Odisha and Arunachal Pradesh have shown impressive growth (20%-120% increase) in terms of both cultivated area and production of small millets. This rise could be due to several factors like economic benefits from higher market prices for small millets in these regions, supportive government policies, or changing weather patterns that make these areas more suitable for the crop. Cultural shifts towards healthier food choices or the ease of integrating small millets into mechanised farming practices also play a role.

The contrasting trends highlight the need for targeted interventions. While states like Karnataka, Odisha and Arunachal Pradesh hold promise for future development,

areas experiencing decline in production require strategies to address the new challenges. Promoting small millets through research, favorable policies and addressing cultural factors influencing food habits could be crucial. Given their nutritional value and adaptability, supporting small millets cultivation could significantly contribute to India's food security and agricultural diversity.

1.4 Consumption Pattern of Millets in India

India recorded an approximate consumption of 17.75 metric million tonnes (MMT) of millets in 2023. The compound annual growth rate (CAGR) of the consumption was in the order of 1% over the decade starting from 2012, when the consumption was 16.05 MMT. While consumption of sorghum witnessed a decline within the broader spectrum of millet consumption, the consumption of other millet varieties displayed an upward trend. This shift in consumption patterns suggests an increasing recognition of the health benefits associated with these alternate millet types. Studies have shown that between 1980 and 2010, the annual per capita consumption of sorghum declined sharply amongst rural and urban consumers (Rao and Basavaraj 2015). In the case of pearl millet, per capita consumption was higher in rural areas than in urban areas, though the consumption has declined by over 85% in both urban and rural areas since the introduction of Green Revolution (Basavaraj *et al.*, 2010). This decline is largely due to increased incomes that encourage people to substitute fine cereals, such as rice and wheat, for sorghum.

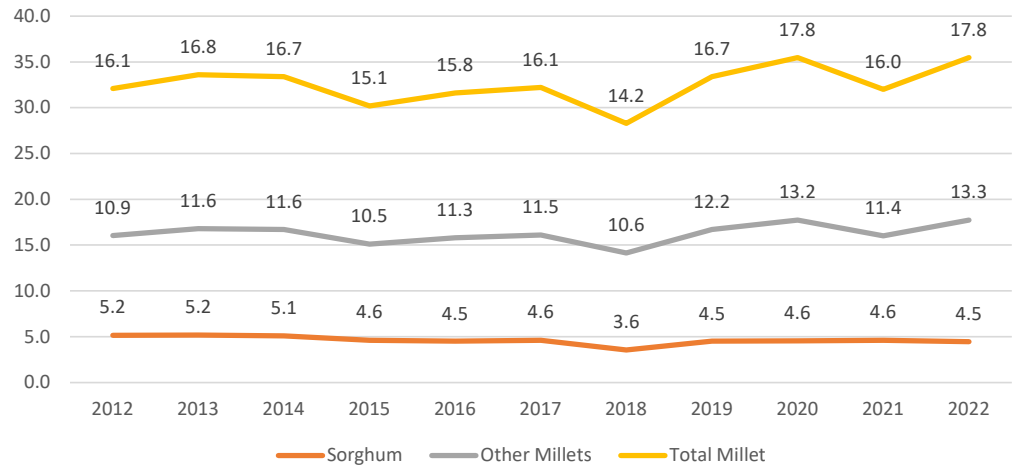
Figure 7 provides insights into the millet consumption pattern in India over 2012-2022 (APEDA and Yes Bank, 2022). Furthermore, Table 2 outlines the current pattern of millet usage, categorising them into feed and FSI (food, seed and industrial) purposes. Specifically, in the year 2022, sorghum saw a utilisation of approximately 0.45 MMT for feed purposes and around 4.00 MMT for FSI purposes. Similarly, other millet varieties saw around 1.60 MMT being used for feed, whereas a substantial 11.70 MMT were utilised for FSI applications.

Table 2: End Use of Millets in India in 2022 (MMT, %)

Use of Millets	Quantity (MMT)	Percentage (%)
Sorghum FSI Consumption	4.00	22.0
Sorghum Feed Consumption	0.45	3.0
Other Millets Feed Consumption	1.60	9.0
Other Millets FSI Consumption	11.70	66.0

Source: APEDA and Yes Bank (2022)

Figure 7: Annual Millet Consumption in India, 2012-2022 (Million Metric Tonnes (in %))



Source: APEDA and Yes Bank (2022).

The per capita consumption of millets in India has experienced a notable decline, dwindling from 30.94 kg per annum in 1960 to 3.87 kg per annum in 2022 (Figure 8). This decline can be attributed to the relatively stagnant production levels of millets, when country's population witnessed a continuous rise.

1.4.1 Recent Trends in Millet Consumption in India

Recently, there has been a growing emphasis on millet production and consumption, driven by concerns about climate change and the increasing awareness about nutritional benefits of millets. Studies have revealed that higher millet prices deter consumption, but increased finger millet prices boost demand for other millet varieties. Changes in income does not affect millet consumption, as they are traditional staples.

Figure 8: Annual Per Capita Consumption of Millets in India (kg)

Source: Same as Figure 7

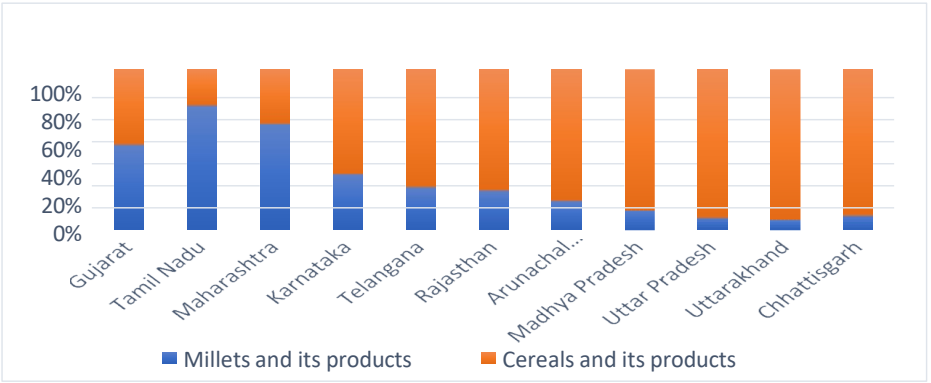
Urban areas show a preference for finger millet, and the aged household heads tend to consume more millets, whereas higher education is associated with lower millet consumption (Umanath *et al.*, 2018). Enhancing value addition through improved and novel processing methods could stimulate millet consumption among urban and high income population, while promoting post-harvest processing in rural areas could create employment opportunities and foster agribusiness development.

Millet consumption patterns in India vary significantly across regions and urban centers. Ahmedabad and Bengaluru lead in the consumption of ready-to-eat millet products among metro cities. Southern states demonstrate diverse millet preparations: Karnataka favours kali, upma and idli, whereas Tamil Nadu prefers millet porridge and koozh. In rural Karnataka, plain cooked millets, upma and paddu are common, suggesting regional variations in preparation methods (Priya *et al.*, 2024).

A study was carried out by ICAR-IIMR to understand the consumption pattern of farm households in selected states. The monthly expenditure patterns on millets and millet products exhibited significant variations across these states. Maharashtra showed a monthly expenditure of ₹300 on millets which was surpassed by Tamil Nadu with ₹350 and Gujarat with ₹450. Karnataka also has a notable expenditure of ₹157 on millets, aligning with its reputation for millet cultivation. In contrast, expenditure was much lower in states like Chhattisgarh (₹16), Arunachal Pradesh (₹38) and Uttarakhand (₹32) indicating lesser presence of millets in their local dietary habits. Interestingly, Telangana, despite being a traditional millet growing region, shows a moderate expenditure of ₹143. States like Rajasthan (₹53) and Madhya Pradesh (₹37) display modest millet expenditures, suggesting potential for increasing millet consumption. These variations in expenditure patterns reflect not only dietary preferences but also factors such as local agricultural practices, market availability of millet products and possible income levels. The data highlights the need for targeted strategies to promote millet consumption, especially in states with lower expenditure, to leverage the nutritional and environmental benefits of these crops.

The quantity of millets and millet products consumed showed significant variations across states, reflecting diverse dietary habits and agricultural practices. Maharashtra stands out as the largest consumer of millets, with an impressive 53.8 kg per capita consumption, far exceeding other states. It is followed by Gujarat at 17 kg and Karnataka at 5.49 kg. In contrast, millet consumption is relatively lower in states like

Figure 9: Pattern of Consumption Expenditure of Farm Households in India (Selected States)



Source: Primary data collected by ICAR-IIMR

Chhattisgarh (1.5 kg), Arunachal Pradesh (1.89 kg) and Uttarakhand (1.17 kg). Interestingly, some states known for their traditional millet cultivation, such as Rajasthan (2.2 kg) and Madhya Pradesh (2.75 kg), show moderate consumption levels. Southern states like Telangana (3.2 kg) and Tamil Nadu (3 kg) maintain a consistent millet presence in their diets. These variations can be attributed to factors such as local agricultural practices, cultural preferences and the availability of millet-based products. The data suggests that while some states have maintained strong millet consumption traditions, others might benefit from various initiatives undertaken to promote millet consumption on account of their nutritional and environmental benefits. This diverse consumption pattern underscores the need for tailored strategies to boost millet consumption across different regions in the country.

1.5 Review of Literature About Cultivation of Millets

The studies of millet cultivation, production and consumption have been summarised in Tables 3, 4 and 5.

2. Millet Value Chain: An Integrated Approach for Promoting Millets in India

2.1 Millet Value Chain

In recent years, the area under millet cultivation has declined globally, but millet production has gradually increased due to improved productivity. In India, millet production peaked in the 1980s, and since then has declined due to a sharp reduction in the cultivated area (Meena *et al.*, 2021). In India's case, the area under millet

cultivation has fallen by over 60% in the past three decades. Through innovative interventions in the value chain, ICAR-IIMR has worked to revive demand for millets by developing several value-added products. These efforts have led to revitalising the

Table 3: List of Studies on the Cultivation of Millets

Sl.No	English Name	Condition required for cultivation	Author
1	Sorghum	Adaptable to drought, heat and salinity, with efficient use of nitrogen and water. Suited for hot and dry areas with low rainfall.	Aruna *et al.* (2018)
2	Pearl millet	Dry climates, marginal soils, Rainfall 200 mm –500 mm **	FAO & ICRISAT (1996)
3	Finger millet	Resist higher temperatures and salinity, temperature 110 C to 270 C, soil pH of 5 to 8.2 and a medium rainfall environment **	Devi *et al.* (2014)
4	Foxtail millet	Less water **, short duration ***	Vetriventhan *et al.* (2012)
5	Barnyard millet	Drought tolerant, rapid maturation rate **	Gomashe (2017)
6	Kodo millet	High drought resistance, good yields, period of 80–135 days **	Arendt & Dal Bello (2011)
7	Little millet	Less water **, short duration ***	Vetriventhan *et al.* (2012)
8	Proso millet	Less water, Rainfall less than 600 mm, average temperature 170C during daytime	Vetriventhan *et al.* (2012)
9	Browntop Millet	Less water, Rainfall less than 600 mm, average temperature 170 C during daytime	(Gomashe, 2017)

Source: Author's compilation

Representation of Millets in India

Image Credits: ICAR-IIMR

Table 4: Millet Growing Regions in India

Agro Ecosystem	Millets Grown	States
Dryland	Sorghum Pearl Millet Ragi	Karnataka Maharashtra Rajasthan Telangana Andhra Pradesh Uttar Pradesh
Himalayan Ecosystem	Barnyard Millet Ragi Foxtail Millet	Uttarakhand Assam Arunachal Pradesh
Hilly/Tribal Ecosystem	Ragi Kodo Millet Little Millet Proso Millet	Madhya Pradesh Chhattisgarh Tamil Nadu Odisha
Extreme Arid Ecosystem	Pearl Millet	Rajasthan
Coastal Region	Sorghum in Rice fallows	Coastal Andhra Pradesh Coastal Odisha

Source: Compiled by Author

millet sector in India (Rana *et al*., 2022). The value chain model developed by ICAR-IIMR for millets can be replicated in other parts of the world where millets are the main crops. Policymakers and concerned departments should replicate the efforts to inspire and encourage millet farmers to go for commercialisation through various approaches such as inclusion of millets in the public distribution system (PDS), subsidising machinery for processing of millets and nationwide campaigns of millet flagging as a health benefit food (Rao *et al*., 2016).

Value chain in the millet sector begins with production, where farmers cultivate and harvest millet crops using appropriate agronomic practices. This is followed by post-harvest handling activities, such as threshing, cleaning and initial storage. The chain then progresses through various levels of processing: primary processing that involves dehulling and milling; secondary processing that creates value-added products like flakes, puffs and ready-to-eat foods; and tertiary processing that develops more sophisticated convenience foods and instant mixes. Distribution and marketing activities ensure that these products reach retailers and consumers through various channels. The chain extends to the retail stage, where millet and millet-based products are sold through traditional markets, supermarkets and e-commerce platforms. Finally, it culminates in consumption by end-users in households, restaurants

Table 5: Review of Literature On Millets Production and Consumption

Study	Summary	Authors
Global scenario of millets cultivation	Millets are crucial in drylands, especially in Africa and Asia, though their global cultivation area has decreased by 25.7% since 1961. Despite this, millet productivity has increased by 36%, with Africa showing the highest growth. India remains the largest millet producer, contributing 37.5% to the global output. The decline in millet cultivation is attributed to a shift towards other crops, changing food habits and assured irrigation.	Meena *et al.* (2021)
Millets: a solution to agrarian and nutritional challenges	Millets are resilient to climate change, and can grow in marginal conditions, making them vital for dryland farming. They are rich in nutrients, which can help to combat nutritional deficiencies, making them essential for future food and nutritional security.	Kumar *et al.* (2018)
Millet production and consumption in India: where do we stand and where do we go?	Millet cultivation in India has declined except for bajra, which shows asurplus. In contrast, jowar and ragi face future deficits. Increasing productivity through new varieties and better management practices can address this issue.	Sreekala *et al.* (2023)
Roadmap for doubling the millet farmers' income by 2021-22	Doubling farmers' income is critical, especially in dryland areas millets are cultivated. Millets' resilience to adverse conditions makes them essential for income growth in these regions, necessitating targeted policy interventions.	Rao *et al.* (2017)
Research progress in millets - biblio-metric evidence from India	Millet research in India has grown, with significant contributions from Indian scholars. Key states like Rajasthan, Karnataka and Maharashtra lead in millet produ-ction. The study highlights the	Akhilraj *et al.* (2023)

(Contd....)

Table 5: Review of Literature On Millets Production and Consumption *(Contd....)*

Study	Summary	Authors
	importance of continued research and innovation in millet cultivation.	
Correlates of millets cultivation in India: empirical evidence from large scale household survey	Bajra and jowar are the most cultivated millets in India, with production varying by region and irrigation availability. Factors like farm size, income and region influence millet cultivation. Elderly and less educated farmers with small land holdings face challenges in millet farming.	Joseph *et al.* (2023)
Choice of millets cultivation in India: an evidence from farm household survey data	Millet prices are a key determinant in farmers' decision to cultivate millets. Ensuring higher prices can encourage expansion in millet cultivation, contributing to sustainable development goals.	Malaiarasan *et al.* (2022)
Farmers' awareness of millets in the Marathwada region	Awareness of different millet types varies, with great millet and pearl millet being most recognised. Consumption is influenced by taste and health benefits. Training and awareness campaigns can boost millet adoption.	Mani *et al.* (2024)
Status of millets in India: trends and prospects	Millet cultivation in India has declined but is seeing a revival due to government initiatives and rising demand for nutritious food. Top millet producing states include Rajasthan, Maharashtra and Karnataka. Outreach programmes are essential for sustained growth.	Sendhil *et al.* (2023)
Millets: the future crops for the tropics -status, challenges, and future prospects	Millets, despite their benefits, face challenges like limited research, market linkages and awareness. Promoting millet-based value chains and integrating them into national food policies can support sustainable agricultural growth.	Kheya *et al.* (2023)

(Contd....)

Table 5: Review of Literature On Millets Production and Consumption *(Concluded)*

Study	Summary	Authors
Economic importance of sorghum	Sorghum is a staple in many countries, used for food, fodder and biofuel. Its cultivation area has declined, but it remains vital in Africa. There is a growing demand for sorghum in animal feed and industrial uses.	Gowri and Shivakumar (2020)
Enabling markets, trade, and policies for enhancing sorghum uptake	Sorghum's use as a staple food is declining in Asia, with rising demand for alternative uses like poultry feed and alcohol production. Market and trade policies are needed to support sorghum's growing role in non-food uses.	Pingali *et al.* (2020)

Source: Author's compilation.

and institutions. Throughout this process, support services such as research and development, quality control, financial services and policy support play crucial role in enhancing the chain's efficiency and effectiveness. The millet value chain's overall performance significantly impacts product quality, pricing and accessibility, influencing farmers' income and consumer nutrition while driving the development of the millet sector. Initially, the millet supply chain was fragmented and lacked proper organisation; there was little coordination between different stages of the chain from farmers to processors to retailers. This disorganisation led to inefficiencies, higher costs and difficulties in getting millet products to market effectively.

The development of processed food (ready-to-eat/ready-to-cook) using millet is proposed as the way forward. Effort should be directed towards the development of new products and processing technologies to overcome the constraints and enhance the shelf life of millets and their value-added products. There is a pertinent need to create public awareness and change consumption perception for millets through emotional and engaging marketing approaches. The ICAR-IIMR recognised these issues and acted by leading a group effort (consortium) to intervene in the millet value chain. This intervention was aimed at addressing the disorganisation and improving the overall efficiency and effectiveness of the millet industry. The ICAR-IIMR worked to bring together various stakeholders from different sectors of the millet industry, including farmers, processors, distributors, retailers, researchers and policymakers. By creating this consortium, IIMR aimed to foster collaboration

and coordination among these different groups, which is crucial for improving the entire value chain.

2.2 Interventions of ICAR-IIMR in Millet Value Chain

2.2.1 Production

Small and marginal farmers play a vital role in millet production, which may be enhanced through quality seed production chain by backward integration with FPO. About 31 FPOs are being modelled by ICAR-IIMR to achieve the same. Studies show that producer companies can become part of modern supply chains in India (Trebbin, 2014). Farmer organisations can improve farmers' access to markets, but they often need support to organise themselves formally (Markelova *et al.*, 2009).

- On-Farm production: The backward integration model of product specific on-farm production covering 3,000 acres in Parbhani (Rabi) and Nanded (Kharif)

Image Credits: ICAR-IIMR

districts of Maharashtra and Adilabad (Kharif for 2 seasons) district in Telangana were tested for four successful years under e-Choupal market assured model of ITC (ABD). The recommended package of practices (PoP) for receiving better yield and quality was extended in public-private-partnership (PPP) mode of farm extension services. This had resulted in an increase in farm productivity and assured net incomes over the benchmarks determined during the baseline survey conducted earlier, and this, in turn, led to a shift in the allocation of sorghum cultivation from marginal to better soil and water rich environments, which is an indicator of stabilisation of acreage in the study area. In fact, backward integration resulted in an overall improvement in the crop scenario such as the quality of the produce (sorghum grain), better utilisation of fallow land and a commercial colour to the crop through sustainable linkage among all the stakeholders in the value chain.

- Impact on cultivation: The backward integration approach improved the overall crop scenario, enhancing the quality of sorghum grains and better utilisation of fallow land. It created a commercial appeal for sorghum, leading to its cultivation on better soil and water rich environments, indicating a stabilisation of acreage in the study areas.

The ICAR-IIMR was engaged in the promotion of millets through FPOs and doubling farmers' income in view of the IYM 2023. The institute is acting as a cluster-based business organisation (CBBO) for the promotion and handholding of 33 millets FPOs in four states (Andhra Pradesh, Karnataka, Telangana and Madhya Pradesh) to implement its "Millets FPO Model". The ICAR-IIMR developed business models for its FPOs based on the regional context and with available resources. The success of FPOs requires assessing multiple factors and considering both quantitative and qualitative indicators. The experiences shared by millet FPOs would positively influence millet farming communities and contribute to the growth of millet cultivation. Establishing reliable market linkages, primary processing units and promoting value addition are crucial for the success of millet FPOs (Table 6).

2.2.2 Processing of Millets and Value Addition

Processing of millets has been revolutionised by advances in post-harvest processing and value addition technologies. Millets are now processed into a variety of products, including flour, flakes and ready-to-eat snacks. This has made millets more

Table 6: Success of FPO Millets Model Developed by ICAR-IIMR, Hyderabad

SI. No.	State	Implementing Agency	FPOs (Numbers)
1.	Karnataka	WDD	09
		SFAC	14
2.	Telangana	NABARD	05
		NCDC	02
		SFAC	01
3.	Andhra Pradesh	SFAC	02
		NABARD	07
4.	Madhya Pradesh	SFAC	01
	Total		41

Note: WDD refers to Watershed Development Programme; SFAC is Small Farmers' Agri-Business Consortium; NCDC is National Cooperative Development Corporation; NABARD is National Bank for Agriculture and Rural Development.

Source: Sangappa *et al.* (2023).

appealing to both rural and urban consumers (Verma and Patel, 2013). Several value-added millet products were produced through new technologies under a brand called Eatrite owned and established by ICAR-IIMR, Hyderabad. The same machinery is being scaled up for commercialisation.

Centre of Excellence on Millets

This has paved the way for competitive value addition and product diversity in the millet sector with more than 300 brands launched by startups supported by Nutrihub, ICAR-IIMR. Millet processing and value addition have become increasingly important in the food industry, particularly after growing recognition of millets' nutritional benefits. The primary goal of processing is to enhance consumer acceptability and convenience, which is crucial in countering the trend of decreased millet consumption that often accompanies with rising incomes. As economic status of people improves, there is a tendency to shift towards wheat and rice products, which are generally easier to prepare and have better shelf lifes. However, effective processing techniques can make millet products equally appealing and convenient.

- Primary processing: It is the stage where raw grains are transformed into an edible form. The approach differs based on the type of millet. Naked grains like sorghum, pearl millet and finger millet require minimal processing as their outer layers are easily removed during harvesting. On the other hand,

husked grains such as little, proso, kodo, barnyard, brown top and foxtail millets need more intensive processing to remove their inedible husks. This is typically followed by de-branning to achieve the desired level of refinement. While small-scale milling machinery is available, there is a growing need for higher capacity machines to meet the increasing demand and make processing more economically viable for larger operations. Pre-processing involves cleaning the harvested grains. Traditional harvesting methods often result in a mix of immature grains, chaff, mud particles, stones and other impurities. Modern cleaning equipment such as de-stoners, graders and aspirator systems are now being employed to efficiently remove these contaminants. This step is crucial for improving the quality of the final products and ensuring food safety.

- Secondary processing: It is the stage where significant value addition occurs. This stage involves converting primary processed grains into a variety of ready-to-eat (RTE) and ready-to-cook (RTC) products. These include popular items like puffs, flakes, muesli, extruded snacks, cookies, vermicelli, pasta and instant mixes. The development of these products has greatly expanded the ways in which millets can be consumed, making them more appealing to modern consumers. Various processing methods are employed at this stage, including germination, malting, thermal processing, soaking and fermentation. These techniques not only improve taste and texture, but also enhance the bioavailability of nutrients and reduce antinutrients like phytates.

    a. Milling: It involves separating the bran and germ from the starchy endosperm, which is then ground into flour or semolina. The particle size of the milled product is crucial, as it affects the product's suitability for different applications. For instance, fine flour is better suited for products like roti and cookies, while coarser semolina is ideal for products like vermicelli and pasta. The milling process typically uses equipment such as chakki mills, pulverisers and hammer mills. The shelf life of millet flour is generally 3-4 months, while semolina can last up to 6 months under proper storage conditions.

    b. Flaking technology: It is an important processing method, particularly for creating breakfast cereals and snack products. This process involves hydrating the grains, roasting them and then pressing them into flattened

flakes. Two main methods are used: edge runner technology and roller flakes technology. Each method has its advantages, and is suited to different types of millets. Extending the shelf life of flakes can be a challenge, but proper drying techniques and appropriate packaging can significantly extend their usability.

c. Extrusion technology: It has opened up new possibilities in millet processing. Cold extrusion is used for products like vermicelli, pasta and noodles, while hot extrusion is employed for creating puffed snacks, weaning foods and other ready-to-eat products. Hot extrusion uses high temperatures and pressure to gelatinise starch and denature proteins, which improves digestibility and creates unique textures.

d. Expansion technologies: It involves processes puffing and popping that create light, crispy snacks. The gun popping method, traditionally used for popcorn, has been adapted for millets to create puffed products with appealing textures and flavors. These can further be enhanced with various seasonings and used in products like nutrition bars and breakfast cereals.

e. Baking technology: It involves creation of millet-based versions of popular baked goods like cookies, biscuits, bread and cakes. However, the lack of gluten in millets presents challenges, particularly in products like bread that rely on gluten for structure and texture. Researchers and food technologists are working on ways to overcome these challenges, such as using various binding agents or blending millet flour with wheat flour.

- Tertiary processing: It represents the highest level of value addition in millet processing. This involves creating sophisticated convenience foods that cater to the demands of modern consumers. Products in this category include various instant mixes for traditional dishes, which allow consumers to quickly prepare nutritious millet-based meals at home. The future of millet processing lies in the development and application of advanced technologies like retort pouching, high pressure processing, pulsed electric fields and ohmic heating. These technologies have the potential to further improve the quality, safety and shelf life of millet products while maintaining their nutritional benefits.

2.2.3 Nutritional Evaluation for Mainstreaming

Millets are evaluated for their nutritional composition and health benefits. This information can be used to educate consumers about the nutritional value of millets and encourage them to include these grains in their diet. The findings can be further validated by institutions such as Indian Council for Medical Research - National Institute of Nutrition (ICMR-NIN) and the Council of Scientific and Industrial Research - Central Food Technological Research Institute (CSIR-CFTRI). This would help to increase demand for millets and make them a more sustainable and nutritious crop (Kaushik *et al.*, 2021). Products evaluated may be mainstreamed through public funded programmes on a pilot basis before being rolled out in the Integrated Child Development Services (ICDS) programmes by state governments. Understanding consumer food labelling preferences can also benefit all stakeholders in the food chain. Policymakers can use this information to develop regulations that meet consumer needs, while agricultural producers and retailers can use it to make better marketing decisions (Tran *et al.*, 2022).

Common Facility Established at Nutrihub, ICAR-IIMR

Automated Primary Processing Line

Flour & Semolina Line

Primary Processing

Baking Line

Hot Extruder

Cold Extruder

Noodles Machine

Secondary Processing

Puffing Machine

Nutri Bar Machine

Murukku Machine

Packaging Line

Image Credits: Nutrihub, ICAR-IIMR, Hyderabad

The NIN' organoleptic study of 20 millet products developed by the ICAR-IIMR-shows that millet products are superior to rice products and on par with wheat-based products. This study was followed by investigating the nutritional benefits of millet products in diabetes and school children. The studies established that millets offered better nutrition in general over the available products made from wheat, rice and maize. The amino acid profile of pulse (soy blend) incorporated millet products ensured adequate lysine, which was a limiting factor in millets and also helped overcome the deficiency of micro nutrients. The glycemic index of millet foods was analysed to determine the mean glycemic response for reference and test foods, using international standards. The study reported that there was a decrease in the mean incremental area under glucose curve (IAUC) levels after consuming millet products. Millets commonly synthesise a range of secondary metabolites to protect themselves against adverse conditions. These metabolites are named anti-nutritional factors, and the existence of these factors in millets might reduce the accessibility of nutrients in humans. Some of these factors include protease inhibitors, tannins, non-starch polysaccharides-glucans, phytates and oxalates - each of which might directly or indirectly affect the digestibility and absorption of nutrients. Methods like soaking, germination, autoclaving, de-branning and exogenous enzymes have been used to reduce the anti-nutritional factors and elevate the bioavailability of the nutrients. Animal sources of heme iron are well known for their high bioavailability. However, animal foods are not always affordable to the poorest segments of the population. A vegetarian population requires alternative plant sources having good absorbable iron to tackle iron deficiency.

Most of the cereals, such as wheat flour, brown rice and barley, contain phytic acid at far higher levels than millets. Yet phytate content of millets is often overly emphasized. Finger millet is one of the calcium dense foods, with three times the level of calcium than milk, and the only cereal that contains high calcium content, which is consistent across different varieties (364 ± 58 mg/100 g). Thus, finger millet has the potential for addressing calcium deficiency naturally. Further studies are needed on the design and impact of finger millet-based diets on bone health for infants and children, especially during adolescence, and the prevention of osteoporosis later. Trace mineral contents of pearl millet are 2 to 10 times higher than that of rice. Studies have indicated that percent dialysability of zinc and copper is higher for rice-based diets than pearl millet-based diets. However, total dialysable iron, copper and manganese in pearl millet diet were 2 to 4 times higher than rice-based diet.

Effect of Processing on Nutrient Value of Millets

To address global food insecurity, leveraging millet crops through effective processing is vital for developing nutritious, affordable and appealing food. Food processing enhances nutrient bioavailability, taste and texture while reducing antinutritional factors. Key techniques include decortication, milling, soaking, cooking, roasting, germination and fermentation, each affecting the food's physical and nutritional properties. Processing is divided into primary and secondary stages. Primary processing involves cleaning, dehulling and milling, while secondary processing transforms these into ready-to-cook or ready-to-eat products through methods like flaking and baking. Traditional techniques aim to improve shelf life, texture and nutritional quality. By processing millets, we can increase their consumption and nutritional value by reducing antinutritional compounds and enhancing digestibility. Understanding these effects is crucial for optimising millet utilisation to boost regional food security.

a. Dehulling/Debranning: Dehulling removes the outer hull and pericarp of grains, which is necessary for further processing. However, excessive dehulling could lead to a loss of dietary fiber, bioactive compounds, and up to 80% of phenolic content, which are concentrated in the husk. Studies on pearl millet using traditional and modern dehullers show a reduction in protein, crude fiber, oil, ash, tannins, phytic acid, calcium, iron and phosphorus. Modern dehulling methods tend to reduce antinutrients and improve protein digestibility, though they also increase the estimated glycemic index. Although decortication leads to some nutrient loss, it improves mineral bioavailability and is essential for the efficient production of edible food products. Modern techniques offer advantages over traditional methods in terms of time, cost and labour.

b. Soaking: Soaking grains is a common household practice that enhances mineral bioavailability by reducing anti-nutrients. Research shows that soaking finger millet in distilled water decreases phytic acid content, with significant reductions over different soaking durations: 250 mg/100 g for 12 hours, 241 mg/100 g for 24 hours and 221 mg/100 g for 48 hours. The reduction is due to phytase activity and leaching into the soaking water. However, soaking also leads to reduced iron and zinc levels, likely due to mineral leaching. Additionally, soaking decreases polyphenolic content; overnight soaking of

pearl and finger millet reduced polyphenols from 241.47 genicular artery embolisation (GAE) mg/100 g to 184.43 GAE mg/100 g and from 161.64 GAE mg/100 g to 128.97 GAE mg/100 g, respectively. This reduction is attributed to the activation of polyphenol oxidase. Soaking improves protein digestibility from 62.3% to 76% by removing anti-nutrients that inhibit digestion. It also enhances starch digestibility by leaching out anti-nutrients that obstruct amylase enzymes. Overall, soaking induces various nutritional and functional changes in grains.

c. Germination: Germination starts when dry seeds absorb water and ends with the radicle's elongation. This process triggers metabolic activities that convert fats to sugars and enhances the grain's nutritional and functional properties while reducing anti-nutrients (Ahmed, 2019). Germination can significantly increase the protein, fiber and mineral content of grains like pearl millet, finger millet and kodo millet (Akinola *et al*., 2017). It also reduces fat content, potentially due to increased enzyme activity (Najdi *et al*., 2016). Additionally, germination improves protein digestibility and reduces anti-nutrients like phytic acid and tannins (Chauhan and Sarita, 2018; Sharma and Gujral, 2020). Overall, germination enhances the nutritional value and functional properties of grains, making them more suitable for healthy food formulations.

d. Milling: Milling grinds grains to separate the endosperm, bran and germ, producing refined flour and reducing particle size (Rani *et al*., 2018). This process removes bran, which contains phytic acid and polyphenols, lowering these compounds in the final flour (Rathore, 2016). However, milling also leads to significant nutrient losses, as vitamins and minerals are mainly in the bran (Amadou, 2019). For instance, milling reduces vitamin B, vitamin E, iron, zinc and calcium levels in millet (Taylor and Kruger, 2018; Oghbaei and Prakash, 2016). Despite these losses, milling improves protein and starch digestibility by removing anti-nutrients and reducing particle size (Rathore, 2016; Li *et al*., 2014). Advanced milling technologies are needed to maintain the nutritional quality of millet flour at an industrial scale.

e. Cooking: Cooking millet, a common household method, affects its nutritional content. Studies show that different cooking methods, such as microwave

and open pan cooking, influence carbohydrate, fat and protein levels in proso and little millets. For instance, microwave cooking increases the carbohydrate content of proso millet but reduces its protein content, whereas pan cooking has the opposite effect. Little millet saw similar trends (Kumar *et al.*, 2020). It also impacts antioxidant activity and starch digestibility. Boiling pearl millet significantly raises phenolic content due to the release of bound phenolics during thermal treatment (Siroha and Sandhu, 2017). Parboiling millet products like porridge and couscous reduces rapidly digestible starch and lowers the expected glycemic index by altering starch composition (Bora *et al.*, 2019). However, cooking can decrease in-vitro protein digestibility by 14%-17% due to changes in protein structure and digestibility issues (Gulati *et al.*, 2017; Gulati *et al.*, 2018). Improved cooking methods are needed to balance nutrient preservation with the benefits of increased digestibility and antioxidant activity.

f. Fermentation: It transforms complex compounds in grains into simpler forms using microorganisms, impacting their nutritional profile and storage properties (Amadou *et al.*, 2014). In millet, fermentation can increase protein and fat content while decreasing ash, fiber and carbohydrates due to microbial activity (Akinola *et al.*, 2017). For instance, pearl millet fermented for 16 hours shows a 15.32% increase in protein (Nour *et al.*, 2018). Additionally, fermentation reduces phytic acid and increases mineral availability and vitamins in finger millet (Konapur *et al.*, 2014). Fermentation also impacts phenolic compounds. It can reduce total phenolics in finger millet by 41% (Gabaza *et al.*, 2016), but may also increase bioactive compounds. For example, using rhizopus azygosporus as a starter culture enhances total phenolic content significantly (Purewal *et al.*, 2019). Moreover, fermentation improves in-vitro protein and starch digestibility in pearl millet, with the highest improvements observed at 30°C (Urooj, 2017; Nour *et al.*, 2018). Overall, fermentation enhances the nutritional quality of millet, making it a valuable technique for producing nutritious food products.

g. Popping: Popping is a high-temperature short-time (HTST) method used to expand grains, making them suitable for snacks and ready-to-eat products (Saleh *et al.*, 2013). This process enhances flavor and aroma, and puffed mil-

let is beneficial due to its high phenolic and mineral content (Kapoor, 2013). Studies show that puffing increases the carbohydrate and protein content of millet while reducing fiber, fat and some minerals like calcium (Patel *et al.*, 2018). For example, puffing kodo millet at 230°C for 3 minutes increased carbohydrates from 68.35% to 74.38% and protein from 7.92% to 8.12%. Popping also improves the nutritional profile of finger millet by increasing protein, carbohydrates and iron, while decreasing calcium, fiber, moisture and fat (Chauhan and Sarita, 2018). Additionally, puffing reduces antinutrients such as phytic acid and tannins, which can enhance mineral bioavailability (Shigihalli *et al.*, 2018). The process also improves the digestibility of proteins and starch. Puffed millet shows higher protein digestibility due to reduced trypsin inhibitor activity and increased starch hydrolysis rates during in-vitro digestion (Huang *et al.*, 2018). Overall, popping is an effective technique for producing nutritious, expanded millet products suitable for consumption.

h. Dry heat treatments: Dry heat treatments are effective in inactivating spoilage microorganisms by reducing moisture and directly targeting microbial activity (Nielsen *et al.*, 2004). For instance, treating pearl millet flour at 100°C for 120 minutes cut free fatty acids (FFA) by 63.6% (Bhati *et al.*, 2016). Similarly, extruding at 110°C for one minute reduced fat acidity, though it increased over time (Jalgaonkar *et al.*, 2016). Roasting finger millet at 97°C lowered crude fat, improving shelf life (Singh *et al.*, 2018). These treatments also affect flour properties – roasted pearl millet flour had reduced phytic acid and trypsin inhibitor activity, enhancing nutritional quality. However, they may cause colour changes, as seen with darker composite bread from extruded finger millet flour and reduced lightness in roasted fonio millet.

i. Microwave: Microwave processing, using non-ionising radiation at 2450 MHz, heats food evenly by interacting with water molecules (Sruthi *et al.*, 2021). It decontaminates food by denaturing enzymes and proteins and breaking down ribosomal RNA (Ribonucleic acid) (Banik *et al.*, 2003). For example, 100 seconds of treatment at 900 W reduced lipase activity in pearl millet flour by 92.9% (Yadav *et al.*, 2012). Microwave treatment also reduces fat acidity, forms maillard reaction products to enhance flavor and antioxi-

dant activity, and alters viscosity and color, making flour suitable for various uses (Adebowale *et al.*, 2020). Further research is needed to understand its effects on microbial decontamination and storage.

j. Infrared heating: Infrared radiation (0.78 to 1000 μm) is used in the food industry for drying, pasteurisation and frying, providing quick and uniform heating. It enhances heat and mass transfer, and its ability to directly heat food materials helps destroy microbial cells, inactivate lipase, and reduce free fatty acid levels. Key factors include wavelength, power and emitter distance. For example, heating sorghum flour at 120°C for 8.5 minutes reduces free fatty acids and lipase activity. Infrared heating also reduces phytic acids and tannins, increases total phenols and decreases viscosity. However, its impact on microbial stability needs further research.

k. Gamma rays: Gamma rays, a type of ionising radiation, extend the shelf life and safety of foods by reducing spoilage and foodborne illnesses (Caceres *et al.*, 2020). The Food and Agriculture Organisation (FAO), the International Atomic Energy Agency (IAEA), and the World Health Organisation (WHO), which work to improve food security and global health, confirm that

Nutritional Evaluation: Key Insights

Effect of processing on antinutrient content of millets

Millets contain antinutrients like phytates, tannins and oxalates that can hinder nutrient absorption. Processing methods such as soaking, germination, fermentation and popping significantly reduce these antinutrients. For example, soaking decreases phytic acid by 10%-41% and polyphenols by 11%-15%. Germination and fermentation lower phytic acid while increasing essential nutrients. These processes enhance millet's nutritional value and digestibility.

Effect of processing on antioxidant activity of millets

Different processing methods have varying impacts on millet's antioxidant activity. Malting and germination generally increase antioxidant properties, with malting finger millet doubling free phenolic acid antioxidants. However, cooking, roasting and dehulling tend to reduce antioxidant activity due to thermal degradation and removal of the antioxidant-rich pericarp. Optimal processing should aim to preserve millet's antioxidant benefits.

Effect of storage on bioactive constituents

Storage duration affects bioactive constituents and minerals in cereal grains. Over time, phenolics undergo polymerization and degradation, altering the bioactive profile. Bioactive derivatives can convert into high-molecular-weight tannins and aglycones, changing phenolic content and sensory attributes. Storage also impacts moisture levels, which can influence sensory qualities. Both processing methods and storage conditions significantly affect the nutritional composition and sensory features of cereal products.

doses up to 10 kg are safe, and do not cause toxicity or significant nutrient loss. Gamma irradiation stabilises millet flour by damaging microbial DNA (Deoxyribonucleic acid), reducing microbial counts, and stabilising moisture content (Mustapha *et al.*, 2014). It also decreases fungal growth, free fatty acids, lipoxygenase activity and malondialdehyde levels, minimising off-flavors (Reddy and Viswanath, 2019). Combining gamma irradiation with heat treatment further reduces microbial load. Additionally, irradiation lowers anti-nutrient levels and improves protein digestibility. Further research is needed to fully understand its effects.

l. High-Pressure Processing (HPP): The HPP is an effective alternative to thermal processing for inactivating food-borne microorganisms and enzymes without chemical preservatives, operating at much lower temperatures (Kaushik *et al.*, 2016). HPP disrupts non-covalent bonds in microbial cells while preserving covalent bonds, maintaining the food's color, aroma, flavor and nutrition (Meng *et al.*, 2018). It also inhibits lipid oxidation, reducing undesirable compounds like aldehydes and ketones (Wang *et al.*, 2018). HPP improves the shelf life of flour by removing or damaging the outer bran layers of grains (Zhu *et al.*, 2016). Although not widely used for millet processing, HPP can enhance flour quality by reducing bound water, increasing phenolic content and antioxidant activity, and improving sensory qualities and protein digestibility in millet flour (Sharma *et al.*, 2018). Further studies are needed to explore HPP potential in millet flour processing.

m. Pulsed light processing: Pulsed light (PL) is a non-thermal method using intense bursts of broad spectrum radiation (200–1100 nm) to treat food surfaces. It inactivates enzymes like lipase and lipoxygenase, preventing lipid oxidation and rancidity (Jeon *et al.*, 2019). The PL also damages microbial DNA, causing cell death, with effective microbial inactivation requiring at least 35 J/cm^2 (Hwang *et al.*, 2018). The PL affects food properties minimally, with negligible changes in water activity, moisture and color in millet samples. However, its effectiveness is reduced for opaque liquids and powders due to limited penetration and shadowing issues.

n. Ultrasonication: Ultrasonication is an emerging food processing technology that uses high-energy sound waves (20 kHz-100 kHz) to enhance processing,

quality and safety. It improves mass transfer, extraction efficiency and nutrient functionality through acoustic cavitation, which creates intense pressures and temperatures that disrupt cell membranes, inactivate enzymes, and generate free radicals (Vanga *et al.*, 2020). Ultrasonication can enhance antioxidant activity and nutritional attributes, as seen in improved radical scavenging in sorghum flour (Sullivan *et al.*, 2018) and increased beneficial compounds in sorghum sprouts (Hassan *et al.*, 2020). Though research on millet is limited, ultrasonication shows potential for boosting nutritional quality and stability in millets.

2.2.4 Commercialisation of Value-Added Technologies

The ICAR-IIMR has commercialised 77 value-added millet technologies through Nutrihub-TBI. The technologies are being scaled up and adopted by the startups and industry to produce novel value-added products. ICAR-IIMR has shared value-added millet technologies with startups through Memorandum of Understanding (MoU) and licensing (Rao *et al.*, 2021). Over 190 startups have been supported in developing and commercialising these technologies. In the realm of food innovation, where wheat and rice have dominated the value-added product landscape, the brand Eatrite emerged as a trailblazer in the millet category. Conceptualised by the ICAR-IIMR, Eatrite represents a concerted effort to transform millets from a traditional, often overlooked grain into a modern, desirable food product. This section narrates the story of Eatrite's inception, development and its pivotal role in the millet value chain, paving the way for millet entrepreneurship and setting a benchmark for future brands.

Conceptualisation of Eatrite

The genesis of Eatrite can be traced back to the identification of a critical gap in the food market. While millets are rich in nutrients and resilient to climate change, their consumption had dwindled due to the perceptions that they involved cumbersome procedure to prepare. Millets also lacked in culinary appeal. The IIMR recognised the need for a paradigm shift – to make millets accessible, palatable and convenient for the modern consumer. Thus, Eatrite was born, a brand aimed at redefining millet consumption through innovative value-added products. Eatrite's product development focused on addressing the key barriers to millet consumption.

"Eatrite" The Brand Owned by ICAR-IIMR

Source: ICAR-IIMR

Ease of preparation: By developing ready-to-cook (RTC) and ready-to-eat (RTE) products, Eatrite made millets convenient for busy lifestyles. Products like millet upma, idli mixes and ready made snacks eliminated the traditional, labour-intensive preparation processes.

Taste and quality: IIMR's rigorous research and development (R&D) ensured that Eatrite products not only retained the nutritional benefits of millets but also appealed to the taste buds. The inclusion of various millet-based recipes and flavors catered to diverse consumer preferences.

Nutritional validation: Collaborated with the NIN for validating superior nutritional profiles of Eatrite products, establishing them as healthy alternatives to conventional grain-based foods.

Commercial viability and demand creation: Eatrite's success as a commercially viable model lies in its strategic approach to demand creation. The brand's marketing campaigns, including both above the line (ATL) and below the line (BTL) strategies, played a crucial role in raising consumer awareness about the health benefits of millets.

Branding and packaging: Eatrite products were branded and packaged to highlight their health benefits, making them attractive to urban consumers. The branding strategy positioned Eatrite as a premium, health-conscious choice.

"Eatrite" Products Commercialised by ICAR-IIMR

Image Credits: Nutrihub, ICAR-IIMR

Incubation Facilities at Nutrihub, ICAR-IIMR

Image Credits: Nutrihub, ICAR-IIMR

Market penetration: Initial commercialisation efforts focused on urban markets through retail chains like Heritage stores in Hyderabad and later expanded to NAFED bazaars in New Delhi. These pilot projects demonstrated the market potential for millet products.

3. Entrepreneurship Development in Millets

The ICAR-IIMR established a Technology Business Incubator (NUTRIHUB) in 2016 to support startups working on millets. The incubator has been successful in helping more than 400 startups to develop and commercialise their products. Entrepreneurship Development Programmes (EDPs) were conducted to expand a thorough understanding of post harvest management, that includes integrating growers through market places, manufacturing, understanding the nutrient value of pearl millets and its commercialisation. To raise awareness of pearl millets among entrepreneurs, aspirants, academicians, housewives, students, etc., ICAR-IIMR regularly organises the following capacity building events.

a) Training on cooking with millets – a monthly one-day training course that teaches how to prepare a variety of millet-based meals.

b) Training on startup ignition – a monthly one-day training course to inform aspiring business owners about new opportunities for business throughout the value chain.

c) Entrepreneurship Development Technology Programmes (TEDP) – a 6-week training course, supported by Department of Science & Technology (DST), Government of India, that covers the complete business possibilities and value chain of pearl millet.

d) Training and technology dissemination – a specialised training to business owners for licenced technologies to prepare them for starting their commercial manufacture.

e) Training to other institutes and universities – aspiring business owners and students are actively trained on outside platforms, including national and international programmes run by different universities, research institutes, incubators, etc.

Nutrihub has supported over 400 startups, facilitating their growth and market entry. These startups have commercialised numerous millet-based products, contributing to the millet value chain's expansion. Under the Rashtriya Krishi Vikas Yojana – Remunerative Approaches for Agriculture and Allied Sectors Rejuvenation (RKVY RAFTAAR) initiative, Nutrihub has evolved as a RABI (Rashtriya Krishi Vikas Yojana

– Remunerative Approaches for Agriculture and Allied Sector Rejuvenation) center. The programme supports startups through:

a) Cohorts and training: Multiple cohorts of startups receive training, mentorship, and funding under structured programmes.

b) Grant disbursement: Financial support for startups is provided under the N-GRAIN and Nutri-cereals Entrepreneurship and Startup Training (NEST) programmes, enabling them to scale their operations.

c) Export registration: Assistance in registering startups for export markets through platforms like Directorate General of Foreign Trade (DGFT) and Agricultural and Processed Food Products Export Development Authority (APEDA).

Nutrihub stands as a testament to the successful integration of innovation, entrepreneurship and sustainability in the millet value chain. By providing comprehensive support to startups, Nutrihub ensures continued growth and commercialisation of millet-based products, paving the way for a healthier and more sustainable future. The following sub-section encapsulates the extensive programmes, events and initiatives that have made Nutrihub a cornerstone in the millet ecosystem, driving the revival and mainstreaming of Shree Anna (millets) in India and beyond.

3.1 Awareness Creation and Promotion

Nutrihub has carried out extensive awareness campaigns on millet production, health benefits and value addition by partnering with state and central government agencies, private industry and other stakeholders to organise cyclotrons, walkathons, seminars, workshops and conventions across the country. The government is raising awareness about millets through training, events, seed distribution and media campaigns (Press Information Bureau, 2023). Close to 100 MoUs with public and private institutes are made to undertake inclusive millets promotion with ICRISAT, CSIR-CFTRI, ICMR-NIN, and many private entrepreneurs and state governments (Rao *et al*., 2021).

Major Events (Including Flagship Events)

- Nutri-cereal conventions: These annual conventions are designed to showcase millet innovations and connect startups with investors, industry experts and

Glimpses of Nutricereal Conventions organized by Nutrihub, ICAR-IIMR

Image Credits: Nutrihub, ICAR-IIMR

other stakeholders. They serve as a platform for knowledge exchange, networking and business development.

- International trade fairs: Nutrihub has associated with the Government of Karnataka as the knowledge partner for organising the International Trade Fair on Organics and Millets.
- State level conclaves: Nutrihub, in collaboration with various state millet missions, has been actively involved in organising promotional events to create awareness and promote millets across India. These events have played a crucial role in showcasing the importance of millets in health, nutrition, business and exports.

Training Programmes

- Value addition in millets: Conducted on various dates, these training programmes aim to educate participants on the different aspects of millet value addition, including production, processing and marketing. They target diverse groups such as women self-help groups (SHGs), farmers and agripreneurs.
- Feed the Future India Triangular Training (FTF-ITT): This programme was organised in 2019 with a focus on creating linkages in millet value addition

Chhattisgarh Millet Carnival Organised by Nutrihub, ICAR-IIMR

Image Credits: Nutrihub, ICAR-IIMR (February 2023)

and marketing for international participants, enhancing their understanding and capacity to promote millets in their respective countries.

- State level workshops: Workshops for agriculture officers and other stakeholders to increase awareness and adoption of millet cultivation and utilisation practices.

Promotional Campaigns

- Road shows and exhibitions: Nutrihub organises and participates in numerous road shows and exhibitions across India to raise awareness about millets. These events include the Organics and Millets International Trade Fair, Krishi Mela and various state level seminars.

- Product launches and demonstrations: Nutrihub supports startups in launching new products and conducting demonstrations to showcase their millet-based innovations to potential customers and partners.

4. Gaps in Millet Value Chain

4.1 Production

- Low productivity: Millets exhibit lower yields compared to wheat, rice and maize, primarily due to cultivation on marginal lands under rainfed condi-

Glimpse of Millet Walkathon Organised by Nutrihub, ICAR-IIMR

Image Credits: Nutrihub, ICAR-IIMR (March 2023)

tions and the limited adoption of improved cultivars. This yield gap in millets reflects the need for significant enhancements in farmers' cultivation practices. The average yield gap for Rabi sorghum, Kharif sorghum, bajra, ragi and small millets in India during 2009-2014 was 58%, 151%, 62%, 183%, and 156%, respectively.

- Susceptibility to pests and diseases: Despite their overall resilience, millets are still susceptible to certain pests and diseases that can cause substantial losses. Sorghum is particularly vulnerable to shoot fly, stem borer and grain mold. Pearl millet is susceptible to downy mildew and blast, while finger millet is susceptible to blast. The lack of high-yielding cultivars with strong resistance to these pests and diseases poses a significant challenge, and management options are primarily limited to agronomic and chemical methods.

- Declining cultivation area: Despite ongoing efforts to promote millet cultivation over the past decades, sorghum, pearl millet, ragi and small millets have experienced a continuous decline in cultivated area. Sorghum has witnessed an average compound growth rate of (-)5.13%, pearl millet of (-)2.85%, ragi

of (-)2.77% and small millets of (-)6.01%. Stabilizing and expanding the area under millet cultivation is crucial for achieving sufficient production.

- Limited expansion in non-traditional areas: Expanding millet cultivation to non-traditional areas, particularly fallow and wastelands, presents an additional opportunity to boost production. These areas offer a more sustainable cultivation option without competing with high-value crops.
- Lack of end-product specific cultivars: The development of cultivars tailored to specific end products is essential for enhancing the quality of final millet products and enabling large scale value addition by major processors. This requires comprehensive geometrical and nutritional evaluations of available cultivars across all major millet growing regions to identify their suitability for different end uses.
- Inadequate seed production: The production of improved millet cultivars is insufficient to meet the current demand. Establishing seed hubs for breeding and producing product-specific cultivars is crucial to establish a demand driven production system. These seed hubs should be capable of delivering high quality seeds at large volumes.

4.2 Processing

4.2.1 Primary Processing Challenges

- Low efficiency of existing machinery: Current dehulling machines exhibit low recovery rates of 70%-80%, resulting in significant losses of unhulled and broken grains.
- Ineffective separation of unhulled grains: The separation of unhulled grains from dehulled grains remains a challenge, necessitating the use of expensive color sorters, which increases processing costs.
- Limited adaptability of dehulling equipment: Single dehuller units are not suitable for processing all types of millets due to their varying morphological characteristics. Multipurpose dehulling equipment capable of handling multiple millet varieties is needed.
- Reduced shelf life of processed grains: Processed grains have a shorter shelf life compared to un-hulled grains. More research work is needed to optimise polishing, milling and other processing steps to extend shelf life.

- Lack of polishing standards: Unlike rice, there are no established standards for the degree of polishing in millets. Studies are needed to develop grading standards and polishing limits to preserve grain quality, nutrition and prevent excessive polishing.

4.2.2 Secondary Processing Challenges

- Gluten-free limitations: Due to the absence of gluten, achieving complete millet-based products like bread and buns remains a challenge. Gluten substitutes or alternative processing techniques need to be explored.
- Lower shelf life of processed products: Extending the shelf life of processed millet products beyond six months is crucial for export market viability.
- Limited product diversification: Current product diversification efforts primarily cater to local preferences. Research and development is needed to expand product varieties for continental and export markets.
- Underdeveloped plant protein and nutraceutical applications: Millets offer potential for plant protein and nutraceutical products, but further research and development is required to fully realise this potential.
- Inadequate data on processing effects: Comprehensive data on the impact of various processing techniques on millet's nutritional characteristics is lacking. A robust framework for optimising processing methods to enhance nutrient bioavailability and reduce antinutrients is needed.
- Quantification of bioactive compounds: Comparative studies are needed to quantify the levels of physiologically active bio compounds, such as polyphenols, antioxidants, resistant starch and prebiotics in processed millets compared to raw millets. Research on the potential medical benefits of millet's anti-inflammatory properties is also warranted.

4.3 Marketing and Policy

- Lack of market linkage: The absence of strong connections between millet producers and consumers hinders the efficient flow of millet products from farms to markets. This disconnect impedes the expansion of millet consumption and limits opportunities for farmers to realise fair prices for their produce.

- Inadequate grading standards: The lack of defined grades and standards for millets in the market creates uncertainty and inconsistencies in quality assessment. This absence of standardised grades makes it difficult to establish certification mechanisms, which poses a significant barrier to millet exports.
- Limited export knowledge: The lack of comprehensive knowledge about export-import policies and regulations pertaining to millets across different countries hinders the ability of exporters to navigate the complexities of international trade. This knowledge gap impedes export efforts and limits millet's global market potential.
- Low consumer awareness: Millets often face negative perception among consumers, who associate them with inferior taste, texture and limited culinary versatility. This perception stems from limited exposure to high quality millet-based products and negative experiences with poorly prepared millet dishes.
- Restricted availability: Millets are not as widely available as staple grains like rice and wheat, particularly in urban areas making it challenging for consumers to access and purchase millet products, further hindering their consumption.
- Inconsistent quality: The quality of millet products can vary considerably due to a lack of standardissed production and processing practices. This inconsistency in quality makes it difficult for consumers to find consistently good millet products, affecting their overall perception and purchasing decisions.
- Limited product variety: The range of millet-based products remains relatively limited compared to other grains, restricting the options available to consumers, thereby, making it a challenge to attract a wider consumer base and expand the market for millet products.
- Price sensitivity: Millet products often carry a higher price tag compared to other grains, making them less attractive to price sensitive consumers hindering the expansion of millet consumption, particularly among low-income households.
- Inadequate marketing efforts: Millets have not received the same level of marketing and promotional support as other grains, contributing to low levels

of consumer awareness and perception of their benefits, limiting the growth of the millet market and hindering its potential to compete with more established grains.

- Availability of other fine cereals at incentivised prices: Fine cereals such as rice and wheat have been made available at incentivised prices through PDS, MDM, WCD and other public-funded feeding/nutritional programmes.
- Inadequate support to research efforts for improving the millets cultivation: While aligning more resources for the improvement of fine cereals, millets were not given adequate importance in research and development on improved varieties, productivity, and diversification of processing technologies and marketing.

Millets face low profitability and limited commercialisation, making them less remunerative crops. This is primarily due to low yields and declining market prices, which are further affected by their sensitivity to environmental factors, as seen in the case of Kharif sorghum. The absence of a minimum support price (MSP) for small millets has hindered their expansion in cultivated area, resulting in reduced production and supply. To address this, there is a pressing need for government procurement mechanisms alongside MSP implementation. Additionally, the slow outreach efforts by institutions and government bodies have led to low public awareness about the nutritional and ecological importance of millets.

Millets have lower productivity than other cereals due to the cultivation of millets in marginal lands, the use of conventional farming practices, and the lack of access to improved varieties. Significant productivity enhancements are impeded by low access to improved technologies such as high-yielding seed varieties (Hamukwala *et al.*, 2010). The current machinery for millet processing is inefficient, leading to grain loss. Additionally, fine cereals are subsidised and available in the market, making it difficult for millets to compete. New processing technologies are needed to improve its quality and appeal (Saleh *et al.*, 2013). Studies have shown that bringing small millets under MSP can further boost the millet cultivation (Garg *et al.*, 2022).

The crops such as rice, wheat and maize have been heavily researched and as a result many advanced technologies are available for their cultivation, processing, value addition and exports. Millet initiatives in the early 2000s focused on production, but

later shifted to consumption with the launch of International Fund for Agricultural Development (IFAD) that promotes the use of neglected and underutilised species (NUS) (IFAD-NUS), ICAR's National Agricultural Innovation Project (NAIP) and Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP). These initiatives gave considerable importance to demand creation by establishing centres of excellence to promote millets through entrepreneurial development, market linkages and awareness campaigns (Pandey and Bolia, 2023).

The past experiences have shown that crops with high levels of crop technology, policy and market driven demand, such as rice, wheat and maize have the potential for significant growth (National Academy of Agricultural Sciences, 2022). Therefore, sorghum, pearl millet, ragi and other small millets may be promoted with a similar strategy. The Government of India has been undertaking several policy and research initiatives to deal with the inefficiencies associated with millets value chain.

5. Model Millet Value Chain

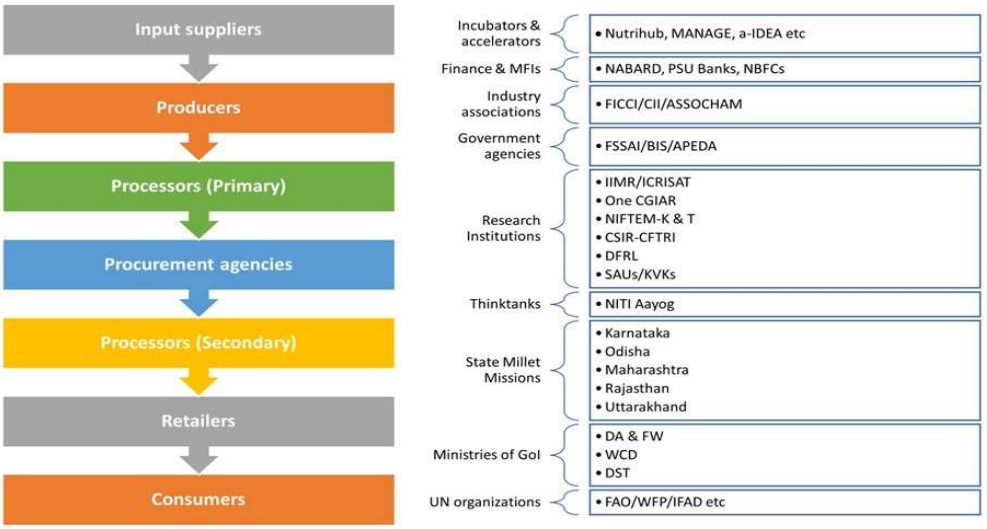
The value chain model is a promising way to promote millets and improve the livelihoods of millet farmers (Figure 10). By replicating the model in other parts of the world, we can help to ensure that millets continue to be a staple food for millions of people.

5.1 Input Suppliers in Millet Cultivation

- Seeds: High quality seeds are the foundation of successful millet cultivation. Quality seed suppliers play a critical role in providing farmers with access to improved varieties of millet seeds. These improved varieties offer enhanced yield, nutritional value and resistance to pests and diseases. Key seed suppliers for millet cultivation include:

  Public sector institutions: Government agencies such as National Seeds Corporation and research institutions like the ICAR-IIMR along with several other ICAR institutions, Krishi Vigyan Kendra (KVKs), state agriculture universities (SAUs) including All India Coordinated Research Project (AICRP) Centres on sorghum, pearl millet and small millets have been developing and providing improved millet seeds (or cultivars/varieties). ICRISAT has also been significantly working on development of

Figure 10: Stakeholders Involved in Millet Value Chain



Source: Schematic Representation of Millet Value Chain by Nutrihub, ICAR-IIMR (2023)

high yielding variety (HYVs) of millets, especially bio-fortified varieties in association with HarvestPlus.

Private seed companies: Numerous private seed companies such as Corteva, Bayer, Syngenta, etc., have been offering a wide range of millet varieties tailored to specific agroecological conditions and farmer preferences.

- Fertilisers: Millet crops require balanced nutrition to achieve optimal growth and yield. Fertiliser suppliers provide farmers with fertilizers containing essential nutrients like nitrogen, phosphorus and potassium (NPK) to enhance soil fertility and support millet plant development. Major fertiliser suppliers for millet cultivation include:

  Cooperative societies: Farmer-owned cooperatives like IFFCO and NFL distribute fertilisers to farmers at affordable prices and ensure adequate availability of these inputs.

  Private fertiliser companies: Private companies like Coromandel International, DCM Shriram, and UPL offer a range of fertilisers specifically formulated for millet cultivation.

- Plant protection chemicals: Plant protection chemicals play a crucial role in safeguarding millet crops from pests and diseases. Pesticide suppliers provide farmers with effective and safe pest control solutions to minimise crop losses and ensure profitable millet production. Multinational corporations like Bayer, Dupont and Syngenta, and Indian companies like UPL, Dhanuka Agritech, and Rallis, etc., are providing cost effective pest control solutions.
- Other necessary inputs: Apart from seeds, fertilisers, and plant protection chemicals, other essential inputs are required for successful millet cultivation. These include:

  Farm machinery: Appropriate farm machinery, such as tractors, threshers and seed drills are being currently used in millet cultivation.

  Irrigation systems: In areas with limited rainfall (in the absence of soil moisture), irrigation is used for providing adequate water to millet crops during critical growth stages.

  Post-harvest storage and handling facilities: Proper post-harvest storage and handling practices are followed to minimise grain losses and maintain the quality and marketability of millet produce.

5.2 Producers: Farmers, FPOs and Tribal Groups

Millet cultivation is deeply rooted in the traditions and livelihoods of farmers, FPOs and tribal groups across India and the world. These producers play a crucial role in preserving millet biodiversity, adapting millet cultivation practices to diverse agro-ecological conditions, and promoting millet consumption for its nutritional benefits.

- Farmers: Smallholder farmers are the backbone of millet cultivation globally. They cultivate millets on diverse landholdings, often under challenging conditions, utilising their traditional knowledge and skills to ensure sustainable millet production.
- FPOs: They are collectives of farmers which empower the farmers to collectively source inputs, access markets and enhance their bargaining power. FPOs are playing a significant role in promoting millet cultivation

by providing farmers with access to improved seeds, training and financial resources.

- Tribal groups: Tribal communities have a long history of cultivating and utilising millets as a staple food source. Their traditional knowledge and practices have been contributing significantly to millet biodiversity and adaptation to diverse environments.

5.3 Millet Processors

Millet processing plays a critical role in transforming raw millet grains into value-added products that can be readily consumed and meet market demands. A diverse range of actors, including government institutions, FPOs, SHGs, small-scale start-ups, non-governmental organisations (NGOs) and large-scale industries, are actively involved in millet processing in India.

- Government institutions: The ICAR plays a crucial role in promoting millet processing and value addition through various initiatives such as establishing processing centres to provide farmers with access to affordable and efficient processing facilities. Further, ICAR supports research and development of innovative millet processing technologies to enhance productivity, quality and shelf life of millet products.

- FPOs are empowering farmers to collectively process and market their millet products. ICAR-IIMR has been supporting more than 33 FPOs in millet cultivation, processing and marketing of millets and their value-added products.

- SHGs, particularly women's groups, are playing a significant role in processing and marketing millets at the local level. They provide employment opportunities for rural women and contribute to their economic empowerment in millet growing regions.

- Several small-scale startups are emerging in India, focusing on innovative millet processing and product development. These startups are introducing new millet-based products, such as millet flour, snacks and breakfast cereals, to expand the market and consumer base for millets.

- NGOs are actively promoting millet processing and consumption through various initiatives, such as (a) imparting training to farmers and SHGs on millet processing techniques, quality control and business management, (b) establishing processing units in rural communities to enhance local processing capacity, and (c) linking farmers to markets to facilitate market linkages between millet processors and buyers, ensuring fair prices and sustainable livelihoods for millet producers.

- Large-scale industries are playing an increasing role in millet processing, driven by the growing demand for millet-based products. These industries are investing in advanced processing technologies and product development to cater to a wider consumer base. Several value-added products are being produced by the industry giants offering a range of product choices to the consumers.

5.4 Millet Procurement and Marketing Agencies: A Diverse Ecosystem

Millet procurement and marketing in India involve a diverse range of actors. Each of these players contributes to the efficient flow of millet produce from farmers to consumers, ensuring market access, price stability and sustainable livelihoods for millet growers.

- Government agencies play a pivotal role in millet procurement and marketing through various initiatives, such as: (a) Price Support Scheme (PSS) providing MSP for millets to protect farmers from price volatility and encourage millet production; (b) National Agricultural Cooperative Marketing Federation of India Limited (NAFED), a central government cooperative, procuring millets directly from farmers and farmer organisations and ensuring market linkages and price stability; and (c) Food Corporation of India (FCI), the nodal agency for public procurement of food grains, procuring millets from surplus producing states for distribution through PDS and other welfare programmes.

- Wholesalers play a crucial role in connecting millet producers to large markets. They aggregate millet produce from farmers and supply it to retailers, distributors and processing units. Wholesalers ensure the availability of millets in bulk quantities and contribute to their price discovery and market expansion.

- Emerging startups are revolutionising millet procurement and marketing through innovative digital platforms and supply chain solutions. These start-ups connect farmers directly to consumers, offering transparent pricing mechanisms, real time market information and hassle free transactions.
- FPOs are empowering farmers to collectively procure and market their millet products. They negotiate better prices for farmers, provide quality control measures and facilitate access to larger markets.
- SHGs, particularly women's groups, are actively involved in millet procurement and marketing at the local level. They collect and sell millets within their communities, creating additional income opportunities for rural women and contributing to local food security.
- NGOs play a crucial role in facilitating millet procurement and marketing, particularly for marginalised communities. They provide training and support to farmers on market linkages, pricing strategies and sustainable practices.
- Large-scale industries are involved in millet procurement to meet the growing demand for millet-based products. These industries directly procure millets from farmers and FPOs, ensuring a steady supply of raw materials for their processing and manufacturing operations.
- Institutions like ICAR-IIMR and ICRISAT provide technical support and guidance to procurement agencies on grading, storage and quality control of millets.

5.5 Millet Processors (Secondary)

Secondary processing of millets involves transforming millet grains into a wide range of value-added products, such as flour, flakes, puffed millet, breakfast cereals, snacks, bakery products and millet-based beverages. This stage of processing plays a crucial role in enhancing the palatability, convenience and marketability of millets, expanding their consumption, and contributing to the growth of the millet industry in India.

- Startups: Several innovative startups are emerging in India, focusing on developing and manufacturing millet-based food products that cater to the

evolving preferences of modern consumers. These startups are introducing millet-based snacks, breakfast cereals, ready-to-eat meals and millet-fortified bakery products, making millets more accessible and appealing to a wider audience.

- Large-scale industries are also playing a significant role in secondary millet processing, driven by the increasing demand for millet-based products. These industries are investing in advanced processing technologies, product development and marketing strategies to establish a strong foothold in the growing millet market.
- Contract manufacturers provide specialised processing services to millet-based food companies. These manufacturers offer expertise in various processing techniques, including milling, extrusion, baking and packaging, enabling companies to focus on product development and branding while outsourcing the manufacturing process.

5.6 Quality Control and Assurance in Millet Processing and Value Addition

Ensuring the quality and safety of millet products is paramount for consumer protection and the sustainability of the millet industry. Quality control and assurance (QC/QA) measures are implemented throughout the millet processing and value addition chain to maintain consistent product quality and adherence to food safety standards. Research and development (R&D) labs play a crucial role in developing and implementing innovative QC/QA methodologies for millet processing and value addition. These labs conduct research on:

- Standardisation of processing techniques: Developing standardised protocols for millet processing to ensure consistency in product quality.
- Quality control parameters: Establishing quality control parameters for millets, such as moisture content, protein content and aflatoxin levels.
- Sensory evaluation: Conducting sensory evaluation studies to assess the sensory attributes of millet products and consumer preferences.
- Shelf-life studies: Determining the shelf life of millet products under various storage conditions to ensure product stability and safety.

5.7 Retailers

Retailers, particularly supermarket chains, play a pivotal role in connecting millet products to consumers and, thereby, expanding their market reach. By providing shelf space and promoting millet products, retailers make millets more accessible and visible to a wider range of consumers. India's retail landscape is evolving, with a growing presence of organised retailers, including supermarket chains, hypermarkets and e-commerce platforms. These retailers are increasingly recognising the potential of millets and are actively incorporating millet-based products into their offerings.

- Supermarket chains: Major supermarket chains in India, such as Big Bazaar, Reliance SMART, D-Mart and Ratnadeep, are stocking a variety of millet products, including flours, flakes, puffed millet, breakfast cereals, snacks and bakery products.
- E-commerce platforms: Online retailers like Amazon, Flipkart and BigBasket offer a wide range of millet-based products, catering to the growing demand for online grocery shopping.
- Specialty/Franchise stores: Dedicated millet stores and organic stores are emerging in India, offering a curated selection of millet products and providing consumers with information about the benefits of millets.

Millets are gaining recognition in global retail markets as well. Major international supermarket chains are expanding their millet offerings to meet the growing demand for healthy and sustainable food options. Government has formulated a strategy, involving Indian missions abroad and global retail supermarkets, such as Lulu group, Carrefour, Al Jazira, Al Maya and Walmart, to establish millet corner for branding and promotion of millets. They offer a variety of millet-based products in their stores worldwide.

5.8 Consumers

Millets are gaining recognition as a staple food in many parts of India and the world. Their high nutritional value, affordability and sustainability make them an attractive choice for consumers from various demographic groups.

- Women: Women play a significant role in millet consumption, both as primary consumers and as key decision-makers in household food choices. Millets

are often preferred by women due to their culinary versatility, ease of preparation and health benefits.

- Pregnant and lactating women: Millets are rich in iron, calcium and folic acid that are essential nutrients for maternal and child health.
- Women facing nutritional deficiencies: Millets can help to address micronutrient deficiencies, such as iron deficiency anemia, prevalent among women.
- Women entrepreneurs: Millets are becoming a source of livelihood for women entrepreneurs involved in its processing, marketing and value addition.
- Children: Millets are a nutritious and easily digestible option for children, providing essential nutrients for their growth and development.
- Infant and young child feeding: Millets can be included in complementary foods for infants and young children, supporting their nutritional needs.
- School meals: Millets are being included in school meals to provide children with access to nutritious and affordable food.
- Snacking options: Millet-based snacks offer a healthy and wholesome alternative for children.
- Adults: Adults are increasingly adopting millets as a part of their healthy and sustainable diets.
- Health conscious individuals: Millets are recognised for their high fiber content, which contributes to digestive health and weight management.
- Gluten intolerant consumers: Millets are naturally gluten-free, making them a suitable choice for individuals with gluten intolerance or celiac disease.
- Sports enthusiasts: Millets provide sustained energy release, making them a good choice for athletes and active individuals.
- Influencers, including celebrities, health experts, and social media personalities, play a crucial role in shaping consumer perceptions of millets.

- Celebrity endorsements are increasing awareness and promoting millets as a trendy and healthy food choice.
- Endorsement by health experts provide credibility and reinforce the nutritional benefits of millets.
- Social media influencers are showcasing creative recipes and promote millet-based products to their followers.
- Global consumption patterns: Millet consumption is gaining momentum worldwide, with increasing awareness of their nutritional value and versatility.
- Developed countries: Millets are gaining popularity in developed countries, particularly among health conscious consumers seeking gluten-free and whole grain options.
- Developing countries: Millets are a staple food in many developing countries, particularly in Africa and Asia, providing food security and nutrition.
- Niche markets: Millets are gaining traction in niche markets, such as organic food and vegan food, due to their sustainable and ethical production practices.

5.9 Actors Facilitating Value Chain

- Incubators and accelerators: Nutrihub is a sector focused incubator supporting startups developing innovative millet-based products and services. It provides a comprehensive support ranging from ideation to product launch in the market including funding support through various schemes and programmes.
- Financial and microfinance institutions (MFIs): These financial institutions provide financial assistance to millet farmers for various purposes, such as cultivation, establishing and upgrading millet processing facilities, and transportation, storage and marketing of millet produce. By providing microloans, MFIs cater to the financial needs of smallholder millet farmers, particularly in underserved areas. In this context, it is worth noting the financial assistance provided by NABARD with a due focus on millet promotion, aligning with the UNGA declaration of 2023 as the International Year of Millets. NABARD provided refinance support of approximately ₹2,000 crore for activities related

to millet cultivation and processing, besides supporting the formation of over 100 FPOs as CBBOs under central sector schemes.

- Industry associations: Industry bodies have been actively promoting millets and supporting millet-based businesses through knowledge dissemination, partnerships, skill development and awareness campaigns. These bodies have greater contribution in facilitating investments, business networking and policy recommendations to the government to support the growth of the millet industry and promote its integration into the mainstream food system.

- Food Safety and Standards Authority of India (FSSAI): FSSAI is playing a crucial role in ensuring the safety and quality of millet products by: (a) setting food safety standards for millet products, including maximum permissible limits (MPLS) for contaminants, labelling requirements and food safety management practices; (b) conducting inspections and audits of millet processing facilities to ensure compliance with food safety standards; and, (c) promoting awareness campaigns on food safety practices for millet processors, traders and consumers. Currently, individual standards for only a few millets like sorghum (jowar), whole and decorticated pearl millet grain (bajra), finger millet (ragi) and amaranth are prescribed in the Food Safety and Standards (Food Product Standards and Food Additives) Regulations, 2011. The FSSAI has now framed a comprehensive group standard for 15 types of millets specifying eight quality parameters such as maximum limits for moisture content, uric acid content, extraneous matter, other edible grains, defects, weevilled grains and immature and shrivelled grains, in order to ensure availability of good quality (standardised) millets in domestic and global markets. FASSI has specified a comprehensive group standard for millets vide Food Safety and Standards (Food Products Standards and Food Additives) Second Amendment Regulations, 2023.

- Bureau of Indian Standards (BIS): BIS contributes to the standardisation and quality improvement of millet products by (a) developing quality standards for millet products, covering parameters such as moisture content, protein content and aflatoxin levels, (b) certifying schemes for millet products, enabling producers to demonstrate adherence to quality standards and gain consumer trust, and (c) promoting the adoption of quality standards among mil-

let stakeholders to ensure consistency and improvement in the overall quality of millet products.

- Research Institutions:

  a. ICAR-IIMR: It is the leading research institute dedicated to millet research in India, and is spearheading the R&D on millets by : (a) developing new and improved millet varieties with higher yield potential, better nutritional quality and resistance to pests and diseases; (b) improving processing techniques to enhance the nutritional value, shelf life and sensory attributes of millet products; and, (c) conducting nutritional studies to assess the nutritional benefits of millets and identify strategies to promote millet consumption for improved nutrition. The IIMR has made notable progress by developing a high capacity dehuller capable of processing up to 950 kg/hr. The institute has conducted comprehensive validation trials for millet processing equipment, measuring crucial parameters such as travel time, input quantity, impurities and efficiency. These trials were performed on different millet types, including little millet, foxtail millet and kodo millet, providing valuable insights into the processing characteristics of each variety.

  b. ICRISAT. It is an international research institute focused on improving agricultural productivity in developing countries, contributing to the millet value chain by (a) developing and promoting sustainable millet-based technologies for cultivation, processing and storage, particularly for small-holder farmers in African countries, and (b) promoting millet-based value chains in collaboration with governments, private sector partners and other research institutions in developing countries.

  c. Other Institutions: Institutions like NIFTEM (Kundli and Thanjavur), CSIR-CFTRI, and DFRL and other food technology institutes in India are focusing on promoting R&D, entrepreneurship development and innovation in the millet sector by developing millet-based products, optimising processing techniques, providing technical consultancy, transferring innovative millet-based technologies, and stepping up market

linkages including incubation and acceleration programmes to support millet-based startups in the country.

d. The Dhan Foundation, in collaboration with TNAU, CFTRI, and McGill University, has developed three prototype dehullers. The single chamber centrifugal dehuller, designed for little and foxtail millet, demonstrated a significant reduction in dehulling time for women operators, cutting the process by 50%-70%. This model was further improved into a double chamber dehuller to accommodate kodo and barnyard millets. Extensive testing was conducted on both prototypes, examining various grain and machine parameters to optimise performance. Additionally, McGill University contributed by developing a household scale rubber roller dehuller.

e. ICAR-Central Institute of Agriculture Engineering in Bhopal has designed and developed the CIAE-Millet Mill, boasting a capacity of 100 kg/h. This mill incorporates several innovative features, including a high coefficient of dehulling (70%-85%), an energy-efficient one hp single phase electric motor, and an integral suction arrangement for husk and dust separation. The mill's cyclone component ensures eco-friendly operation by providing a dust-free environment during the dehulling process. Notably, the CIAE-Millet Mill is capable of processing all types of minor millets and can even dehull grains while preserving the bran layer.

6. State Millet Missions (Major States)

State Millet Missions, established by several states in India, play a pivotal role in promoting millet cultivation, processing and marketing, including demand creation for mainstreaming millets at the state level. These missions provide funding, training and infrastructure support to millet stakeholders coupled with incentives to farmers, state procurement and support to millet businesses in the state. Karnataka, Odisha, Maharashtra, Tamil Nadu, Rajasthan and Uttarakhand have been in the forefront for promoting millets and mainstreaming them in the state. Table 7 provides state-wise snapshots of important initiatives taken by various state governments to promote millet production and consumption.

Table 7: Summary of Interventions by State Governments in the Millet Sector

State	Summary of the Intervention
Andhra Pradesh	• The target for cultivation of millets has been set as 1.66 lakh hectares and efforts are made to create better marketing facilities for millets. • Incentives to entrepreneurs who come forward to set up millet processing units. • Setting up of millet stalls from the village to the state level to encourage consumption of millets as their chosen food. • More than 20 FPOs in the state are trained for millet production, processing and marketing. • Women self-help groups (SHGs) are encouraged to market and promote products made of millets through Mahila Marts.
Arunachal Pradesh	• Mission Arunachal Foxtail Millets' project: Joint initiative to boost millet production and marketing. • Launched in Tirap district, which faces insurgency and drug addiction issues. • One district, one product strategy aims to provide hope and improve livelihood for farmers. Over 1,000 farmers signed up and cultivated the first batch of millets. • Marketing and sales: First batch currently being marketed and would be ready for sale soon. Provides farmers with new income opportunities and promotes healthy food choices.
Chhattisgarh	• Aims to increase productivity from 4.5 quintals to 9 quintals per acre. • ₹9,000 per acre is being provided to farmers. • Target to increase cultivated area from 96,000 hectares to 1.60 lakh hectares. • Chhattisgarh State Minor Forest Produce Federation procured 5,273 tonnes (2021-22) and 13,050 tonnes (2022-23) of millets at support prices. • Millet entrepreneurs are supported to boost millet processing centres. • Increased income and employment through setting up of millet cafes a profitable business venture. • Legislators served millet-only meals in the State Assembly to create awareness.
Karnataka	• Incentive of 10,000 per hectare for minor millet production under the Raithasiri' scheme for enhanced production and productivity. • Prioritising FPOs involved in processing, grading and packing at the field level and further, empanelment of FPOs as procurement agencies to help farmers overcome transportation challenges and receive fair prices.

(Contd.....)

Table 7: Summary of Interventions by State Governments in the Millet Sector *(Contd...)*

State	Summary of the Intervention
	• Inclusion of jowar and ragi in public distribution system (PDS) to increase demand and provide consistent income for farmers. • Stree Samarthya supporting women SHGs to set up millet processing and value addition units with soft loan assistance. • Providing subsidy for purchase of machinery for encouraging millet processing and value addition. • International Trade Fair on Millets and Organics connects farmers companies and institutions in the millet and the organic sector.
Kerala	• Aims to increase millet production to 3,000 tonnes and pulse production to 10,000 tonnes. • Establishing six new millet processing facilities in addition to the existing unit. • Opening millet cafes serving and selling millet-based products to promote consumption. • Encouraging 2.5 million households to cultivate vegetables & millets • Involving all households in the state by 2026 and expected to achieve goals within the next three years.
Madhya Pradesh	• Provides subsidy on advanced certified seeds of coarse cereals (80%). • Training programmes for farmers. • Study tours outside the state. • Fairs, workshops, seminars, food festivals and road shows. • Inclusion of millet dishes in government food programmes. • Millet in mid-day meals and hostels (once a week).
Maharashtra	• Maharashtra Millet Mission: The state government has allocated ₹200 crore for the mission. • Increased production and sales: The Mission is expected to promote the production and sale of millets. • Health benefits: The government hopes that the mission would encourage younger generations to switch to millet-based foods.
Odisha	• Millet cultivation promotion: The state government is investing over ₹2,500 crore to promote millet cultivation. • Procurement target: The procurement target for millets has been increased to 8 lakh MT this year. • Entrepreneurship development: Sundargarh district was awarded a citation for the highest production of millets and entrepreneurship development.
Rajasthan	• Millet processing units: The state government has given a grant assistance of ₹3.37 crore for the establishment of millet processing units.

(Contd.....)

Table 7: Summary of Interventions by State Governments in the Millet Sector *(Concluded)*

State	Summary of the Intervention
	• Free seed distribution: 8.32 lakh mini kits of millet seeds were distributed free of cost to farmers. • Center of excellence: A center of excellence for millets is being set up in Jodhpur.
Tamil Nadu	• Subsidies provided for bringing 50,000 hectares of fallow land under millet cultivation. • Farmers encouraged to diversify to millets. • Support for farmer groups to set up millet processing centers. • Government to procure finger and pearl millet for fair price shops. • Inclusion of millet-based food in government and educational institutions. • Establishment of 25 canteens serving traditional Tamil Nadu millet dishes. • Grant of ₹1 lakh each to 40 SHGs for millet cluster formation through SHGs. • Setting up cafes in district collector offices and Mathi-Poomalai complexes.
Telangana	• Established 50 dedicated millet outlets across the state. • Promotion of millet-based products. • Boost demand for millets to support farmers. • Encourages healthier eating habits among the population. • Provides a platform for women entrepreneurs to thrive. • Offer loans of ₹5 lakh-₹10 lakh to women entrepreneurs. • Provide special vehicles (container shops) for those without a physical retail space.
Uttarakhand	• Millet Mission: The state has allocated ₹73 crore for the mission in the budget. • Mid-day meal programme: Millets are being incorporated into the mid-day meal programme in schools. • Subsidies: The government is providing subsidies for the establishment of millet processing units.
Uttar Pradesh	• Aims to increase millet area from 1.1 million hectares to 2.5 million hectares. • To replace over 15% of paddy acreage with millets and oilseeds. • 100% grant for setting up processing units and making millet-based food. • Distributing millets in place of rice through PDS under National Food Security Act. • Organising festivals, exhibitions and launching exclusive millet outlets. • Engaging women rural entrepreneurs and SHGs in the value chain. • Five-year programme for reviving millets (2023-2027) to promote millet cultivation and consumption.

Source: Compiled from various publications relating to and reports of state millet missions.

7. Ministries of the Government of India

Various ministries of the Government of India play a role in promoting the millet sector. These ministries collaborate to provide support for millet cultivation, processing, marketing and research.

- The Ministry of Agriculture and Farmers Welfare (MoAFW): MoAFW is the nodal ministry for agriculture and implements various programmes to support millet cultivation and farmers. It provides funding for millet cultivation, research and extension activities.
- The Ministry of Food Processing Industries (MoFPI): MoFPI provides support for millet processing, value addition and market access. It offers financial incentives for millet processing units, promotes brand building and facilitates market linkages.
- The Ministry of Commerce and Industries (MoCI): MoCI supports millet export promotion and market development initiatives. It organises trade fairs, promotes millet products in international markets, and facilitates export linkages.
- The Ministry of Rural Development (MoRD): MoRD provides support for millet-based livelihood opportunities under various rural development schemes. It promotes millet cultivation, processing and value addition in rural areas.
- The Ministry of Women and Child Development (MWCD): MWCD promotes the use of millets in nutrition programmes for women and children. It raises awareness about the nutritional benefits of millets and supports the inclusion of millet-based products in anganwadis and other nutrition programmes.

8. Initiatives by the Government of India

- International Year of Millets (IYM2023): The United Nations proclaimed 2023 as the International Year of Millets (IYM2023) to raise awareness of the nutritional and health benefits of millets, and to promote their production and consumption. The IYM2023 was celebrated by countries around the world through a variety of events and activities, such as conferences, workshops, cooking demonstrations and educational programmes. Over 185

Table 8: International Year of Millets – People's Participation

Sl. No.	Ministry	People (in millions)
1	Ministry of Women and Child	157.15
2	Ministry of Rural Develoment	16.55
3	Ministry of Agriculture and Farmers' Welfare	10.62
4	FSSAI	0.84
5	Ministry of Commerce and Industries (APEDA)	0.11
6	Ministry of Tribal Affairs	0.05
7	Ministry of Food Processing Industries	0.03
8	Ministry of Tourism	0.01
9	Ministry of Civil Aviation	0.00
	Ministries (Sum Total)	185.35

Source: Compiled by the author based on various review meetings of International Year of Millets at the Department of Agriculture and Farmers Welfare, Government of India.

million people participated in several initiatives and activities of the various ministries of the Government of India (Table 8).

- Millets and Other Ancient Grains International Research Initiative (MAHARISHI Initiative): This international initiative focuses on research and awareness about agro-biodiversity, food security and nutrition in line with the IYM2023. The MAHARISHI aims at supporting research on the nutritional value of millets, their cultivation and processing, and their potential to contribute to food security and nutrition.

- Promoting millets through G20: India leveraged its G20 presidency to promote millets. It included millets on the agenda of several meetings and events. Millet recipes were served at these events, and millet-based products were showcased. India also partnered with other countries to promote millets and launched several initiatives to boost the production and consumption of millets. The promotion of millets could help to boost the economies of countries that are currently struggling with food insecurity. In this regard, special group meetings were convened for agriculture along with a series of G20 meetings. These meetings emphasised role of millets as a special focus in view of IYM2023. Three agriculture working group meetings were held across different cities in the country to address the current challenges that member nations faced, such as food insecurity, gaps in the global value chain, climate change, employment, etc.

Glimpses of G20 Technical Excursion at ICAR-IIMR

Image Credits -Nutrihub, ICAR-IIMR (June 2023)

- Promotional events by Indian embassies: Embassies of India in more than 140 countries observed IYM2023, and are raising awareness about the importance of millets and role of India in mainstreaming millets across the globe involving the Indian diaspora. Indian embassies were allocated a 'focused month' each in 2023 to promote the humble millet. The following are some of the promotional events organised by Indian embassies across the world.

    a. Promotion of millet recipes by Indian embassies: The Government of India through the embassies in different countries is making efforts to popularise millet recipes by distributing recipe books published by the Ministry of Agriculture.

    b. Millet promotion by serving millet-based food, recipes and snacks in several international meetings.

    c. Millets and Indian cuisine were featured prominently in the lunch served to Prime Minister Narendra Modi at the 3rd Summit of the Forum for India-Pacific Islands Cooperation in Papua New Guinea.

    d. Millets were served at the state dinner hosted by the United States President Joe Biden and First Lady Jill Biden where the first lady herself worked

PM Modi's US State Dinner Showcases a 'Super Healthy' Vegetarian Spread with Millets and Mushrooms

Image Credits: Evelyn Hockstein (June 2023) through The Hindu Business Line

with guest chef Nina Curtis and other White House chefs to prepare a special menu for the Prime Minister.

e. Millet Research Alliance (MIIRA): This is an initiative proposed by India during its G20 presidency. It aims to raise awareness of the importance of millet production by supporting research on these crops and consumption of millets on a global level with a view to address issues of food security and nutrition. The MIIRA aims to connect millet research organisations globally.

f. Promoting millets in the export markets: APEDA, under the aegis of Ministry of Commerce and Industries, had launched a brand building initiative for Indian millets, called 'Shree Anna'. The goal of this initiative is to promote the consumption of millets and create a niche market for Indian millets in the global market. As part of this initiative, APEDA is organising various sampling and tasting campaigns at major destinations around the world. These campaigns would showcase the taste and versatility of millets and help raise awareness of the health benefits of millets.

APEDA is also using cutting edge digital branding techniques to promote millets through social media campaigns, online videos and e-commerce platforms. APEDA has also published e-catalogues for 30 major millet importing countries to facilitate Indian millet exporters.

- Upgrading ICAR-IIMR as the Global Centre of Excellence: ICAR-IIMR is to be upgraded as the Global Centre of Excellence (CoE) on Millets Research and Development. The Global CoE status would enable IIMR to access additional funding and resources to support its research and outreach activities. This would help to accelerate the development of new millet varieties and technologies that are suitable for different agro-climatic conditions.

  a. Long-term Germplasm Storage Facility: The facility aims at strengthening millets gene bank for conservation, trait-specific characterisation and utilisation of millet biodiversity for crop improvement.

  b. Technology Innovation Centre: A dedicated centre for trait, seed and crop improvement of millets for enhancing yield and productivity

  c. National Referral Laboratory for Millets: A nutri-cereal analytical, food safety and quality assurance is to be established to cater to quality control needs for millets and their products.

  d. Centre of Excellence for Millet Value Chain and Business Facilitation: This will become a centre with state of art facility for entrepreneurship, incubation and startup nurturing.

  e. International Knowledge, Skill Development and Capacity Enablement Centre: Establishing one stop centre for showcasing millet technologies and an advanced knowledge centre for imparting training.

  f. Global Facility for Millet Pilots: A facility for pilots on feed, fodder, biofuels, malting, brewing and promotion of industrial utilisation of millets.

  g. Regional Millet Technology Innovation and Outreach Hubs for rapid technology development and dissemination, creation of mini processing and value addition facility, and establishment of millets extension and farmers training centres to provide one-stop-solution to farmers on all aspects of millets production and utilisation.

9. UN Organisations

United Nations organisations, such as the FAO, the World Food Programme (WFP) and the International Fund for Agricultural Development (IFAD) play a crucial role in promoting millet production, consumption and trade at the global level.

- FAO promotes millet cultivation, processing and value addition through various initiatives, including capacity building programmes and policy support. It also advocates for millet inclusion in global food security and nutrition agendas.
- WFP utilises millets in its food assistance programmes providing nutritious and sustainable food aid to vulnerable populations. It promotes local procurement of millets and supports millet-based food security initiatives.
- IFAD supports smallholder millet farmers in developing countries through various programmes, including access to finance, improved agricultural practices and market linkages. It promotes millet-based livelihood opportunities and rural development.

9.1 Initiatives in Collaboration with International Agencies

- NITI Aayog and WFP aim to map and exchange the best practices for mainstreaming millets in Asia and Africa. The initiative will support the documentation of good practices, lessons learned and present an opportunity for sharing experience amongst Asian and African developing countries.
- South-South and Triangular Cooperation (SSTC): India shall offer a policy choice of mutual collaboration through study visits, expert deployment, demonstration sites, peer coaching networks, technology and/or knowledge transfer, and policy dialogues. ICAR-IIMR, being the pioneer in the development of value chain on millets, could play a vital role in delivering the outputs that are needed for achieving the desired results.
- International collaborations by ICRISAT: ICRISAT is supporting African farmers to achieve higher yields. Together with its partners, ICRISAT has developed high yielding, stress resilient and nutrient dense varieties that have been released in many countries. ICRISAT is currently partnering important projects in Kenya, Zimbabwe, Malawi, Zambia, Tanzania, Ethiopia and

Sudan, in addition to working in many countries in West and Central Africa. In these countries, ICRISAT also promotes the adoption of drought tolerant crops for better livelihoods, climate-smart innovations, water and soil conservation, and development of better agri-food systems.

- Sorghum and Millet Innovation Lab (SMIL): SMIL is a Feed the Future Innovation Lab led by Kansas State University. It is a consortium of R&D organisations that are working to improve the production, processing and marketing of sorghum and millet in West and East Africa. SMIL is established with funding from the United States Agency for International Development (USAID). SMIL conducts extensive research and develops new technologies to improve the resiliency of sorghum and millet production in semi-arid regions. SMIL creates and supports food systems and entrepreneurial opportunities to reduce poverty and hunger in West and East Africa and Haiti.

- Smart Food Initiative: It is a global initiative led by ICRISAT to promote the cultivation and consumption of smart foods. Smart foods are crops that are nutritious, healthy, environmentally sustainable and economically beneficial. ICRISAT is working with governments, businesses and other stakeholders to raise awareness of the benefits of smart foods. Millets have been identified as the smart foods for the first year.

- UN Environment Programme (UNEP) and Global Environment Facility (GEF): UNEP and GEF are integrating traditional crop genetic diversity into technology and working towards R&D on millets and underutilised crops to improve the production and marketing of millets and underutilised crops in Nepal. The project aims at providing support for research, training and capacity building.

- Grain Legumes and Dryland Cereals Agri-food Systems (GLDC): The Consultative Group on International Agricultural Research (CGIAR) Research Programme on GLDC (CRP GLDC) is working to increase the productivity, profitability, resilience and marketability of nutritious grain legume and cereal crops grown in Sub-Saharan Africa and South Asia. The CRP GLDC has prioritised integrated research for development of three cereal crops, namely, sorghum, pearl millet and finger millet, which are grown in semi-arid and

sub-humid dryland agro-ecologies. The CRP GLDC is also working on other legume crops, such as chickpea, cowpea, pigeon pea, groundnut, lentil and soybean.

There are a number of international initiatives underway to promote millets and other ancient grains. These initiatives are being led by governments, research organisations and NGOs. The goal of these initiatives is to raise awareness of the nutritional and health benefits of millets, and to promote their production and consumption. With the continued support of governments, research organisations and NGOs, millets have the potential become a major food crop in the years to come.

10. Future Prospects for Millet Value Chain

10.1 Production and Procurement

10.1.1 Collaboration for Quality Seeds

Nutrihub has established a strategic partnership with ITC e-choupal, implementing an innovative buy back option for high quality millet produce. This strategic collaboration specifically targets farmers in Andhra Pradesh, Karnataka and Maharashtra. The initiative serves multiple purposes: (a) ensures a stable and reliable market for millet farmers; (b) incentivises the production of high quality millets; and, (c) creates a direct link between producers and a major corporate entity. By guaranteeing the purchase of quality produce, this programme encourages farmers to adopt best practices in millet cultivation, leading to improved crop quality and yield. Furthermore, it provides farmers with a sense of financial security by ensuring their produce has a guaranteed buyer, thereby, reducing market uncertainties.

10.1.2 Establishment of Seed Hubs

Recognising the critical importance of quality seeds in millet cultivation, Nutrihub has taken a proactive approach for establishing dedicated seed hubs. These specialised centers serve as focal points for the production, quality control and distribution of high grade millet seeds. The seed hubs are strategically located to cater to different agro-climatic zones, ensuring that farmers across regions have access to seeds that are best suited to their local conditions. These hubs employ advanced seed production techniques, rigorous quality control measures and efficient distribution

systems to ensure that farmers receive seeds of the highest genetic purity and germination rates. By providing access to superior quality seeds, Nutrihub is laying a strong foundation for improved crop yields, and production of disease resistance and high quality millets across the country.

10.1.3 Integration with FPOs

Nutrihub has implemented an innovative and multi-faceted approach to enhance the quality of seed production chain through integration with FPOs. The backward integration strategy ensures that FPOs are directly involved in the seed production process. This approach not only guarantees a steady supply of high quality seeds, but also empowers farmers in crucial aspects of the agricultural value chain. The ICAR-IIMR is actively modeling and supporting more than 30 FPOs, providing them with technical knowledge, management skills and market linkages. This support helps to transform FPOs into efficient, self-sustaining entities capable of meeting the seed and produce requirements of their members and wider farming community.

In addition to backward integration, Nutrihub has facilitated forward integration of FPOs with startups and state governments. This forward looking approach creates a robust ecosystem for the distribution of quality seeds and produce. By connecting FPOs with innovative startups, Nutrihub is fostering technological adoption and market oriented production. The involvement of state governments ensures policy support and wider reach. This integrated approach ensures that improved seed varieties and cultivation practices reach farmers efficiently and effectively, while also providing them with better market access for their produce.

10.1.4 State Support and Procurement Assistance

Nutrihub has extended its expertise beyond institutional boundaries to support state level millet initiatives. A notable example is the creation of a comprehensive quality seed chain for states like Chhattisgarh. This intervention goes beyond merely supplying seeds; it involves setting up a complete ecosystem for quality seed production, distribution and utilisation within the state. Nutrihub has provided technical expertise in selecting appropriate millet varieties, training local farmers and agricultural officers in seed production techniques, and establishing quality control mechanisms. Moreover, Nutrihub has played a crucial role in assisting these states in establishing effective procurement systems directly from farmers. This support includes develop-

ing farmer friendly procurement policies, setting up collection centers, implementing fair pricing mechanisms and ensuring timely payments. By facilitating direct procurement from farmers, Nutrihub ensures that producers receive fair prices for their millet crops, thereby, incentivising continued cultivation and quality maintenance. State level engagement also helps in aligning millet production with local nutritional needs and cultural preferences, contributing to food security and dietary diversity.

10.2 Processing and Value Addition

10.2.1 Collaboration for Farm Gate Value Addition

Nutrihub has forged a significant collaboration with ITC and liaised with the Department of Agriculture and Farmers Welfare through the Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP). This multi-stakeholder partnership aims to promote farm gate value addition in the millet sector. The initiative enables farmers to process millets at the source, adding value to their produce before it enters the market. This approach serves multiple purposes: it increases farmers' income by allowing them to capture a larger share of the value chain, reduces post-harvest losses, and improves the overall quality of millet products reaching consumers. The collaboration involves setting up small-scale processing units at the village or farmer cluster level, providing training to farmers and local entrepreneurs in processing techniques, and establishing market linkages for processed millet products. By bringing value addition processes closer to the farm, this initiative is transforming the rural millet economy, creating new employment opportunities, and encouraging a shift from subsistence farming to market oriented production.

10.2.2 Innovation in Millet Processing Machinery

Recognising a critical gap in the millet value chain, Nutrihub has spearheaded the design, development and retrofitting of a comprehensive range of machinery specifically for millet processing. This innovative approach addresses the unique challenges posed by different millet types, which often require specialised equipment for efficient processing. The machinery developed includes de-hullers, graders, pulverisers and packaging units tailored to the specific characteristics of various millet grains. These technological innovations have significantly improved the efficiency and quality of millet processing. The machinery is designed to be scalable, catering to the needs of both small-scale farmers and larger processing units. By making this

equipment available, Nutrihub has removed a major bottleneck in millet value addition, enabling processors to produce high quality millet products consistently. This has not only improved the marketability of millet products, but has also contributed to increased consumer acceptance by ensuring better quality and presentation of millet-based foods.

10.2.3 Brand Development and Product Diversification

In a landmark initiative to showcase the vast potential of millets in the food industry, Nutrihub launched the "eatrite" brand. This brand serves as a platform to demonstrate the diverse applications of millets in contemporary food products. With more than 30 value-added products under the 'eatrite' banner, Nutrihub has successfully illustrated how millets can be incorporated into a wide range of foods, from ready-to-eat snacks to gourmet cuisine ingredients. The product range includes items such as millet-based breakfast cereals, cookies, pasta, energy bars and flour blends. Each product is developed with a focus on nutritional value, taste and convenience, catering to the evolving preferences of health conscious consumers. Through intensive promotion and awareness campaigns, these products have now penetrated markets across the country. This widespread availability has played a crucial role in changing consumer perceptions about millets, positioning them as versatile, nutritious and appealing food options. The success of the 'eatrite' brand has had a ripple effect on the entire millet industry. It has inspired numerous entrepreneurs and food companies to develop their own millet-based product lines, thereby, expanding the market and creating new opportunities along the entire millet value chain.

10.2.4 Establishment of Common Facility Centre (CFC)

To address the challenges of cost-effective processing and support small-scale entrepreneurs, Nutrihub has created dedicated processing infrastructure through a Common Facility Centre (CFC) at its premises. This state-of-the-art facility is equipped with a comprehensive range of millet processing equipment, allowing for the efficient handling of various millet types and processing requirements. The CFC operates on a shared-use model, enabling small-scale processors and entrepreneurs to access advanced millet processing technologies without the need for large capital investment. This approach has significantly lowered the entry barriers for new players in the millet processing sector. The facility offers services such as de-hulling, milling, grading and packaging – all under one roof. Moreover, the CFC serves as a

hub for training and skill development. Nutrihub organises regular workshops and hands-on training sessions at the facility, educating entrepreneurs and food technologists on the nuances of millet processing. This knowledge dissemination is crucial for maintaining high standards of quality and efficiency across the industry. The establishment of the CFC has had a transformative effect on millet processing landscape. It has enabled the production of high quality millet products at competitive prices, improved overall efficiency of the sector, and fostered innovation in product development.

10.2.5 Technology Development and Licensing

In its role as a center of excellence for millet research and development, Nutrihub has made significant strides in technology development. The institute has developed approximately 70 technologies, each accompanied by detailed Standard Operating Procedures (SOPs). These technologies cover a wide spectrum of millet value chain, including improved cultivation practices, post-harvest handling techniques, processing methods and product formulations. The development of these technologies is backed by rigorous scientific research and extensive field testing. Each technology is designed to address specific challenges in millet production, processing, or utilisation, with a focus on enhancing efficiency, quality and marketability. To ensure that these innovations reach the industry and benefit the wider community, Nutrihub has established a streamlined licensing process. The availability of detailed SOPs facilitates smooth transfer of these technologies to startups and established companies alike. This approach not only promotes the adoption of best practices across the industry but also creates new business opportunities in the millet sector. The licensing programme is complemented by technical support and guidance from Nutrihub experts, ensuring that licensees can effectively implement and optimise these technologies. This technology transfer initiative has played a crucial role in driving innovation and standardisation in the millet industry, contributing to the overall growth and professionalisation of the sector.

10.2.6 Entrepreneurship Development

Recognising the pivotal role of entrepreneurship in driving growth and innovation in the millet sector, Nutrihub initiated the 'Start-up Ignition' training programme. This comprehensive initiative is designed to inspire and equip young minds and aspiring entrepreneurs with the knowledge, skills and mindset necessary to venture

successfully into millet-based businesses. The 'Start-up Ignition' programme covers a wide range of topics essential for entrepreneurial success in the millet industry.

- Understanding of millet processing technologies and quality control measures: The programme employs a mix of theoretical sessions, practical workshops and mentoring from successful entrepreneurs and industry experts.
- Participants are encouraged to develop and pitch their business ideas, receiving constructive feedback and guidance.
- By nurturing entrepreneurial talent, this initiative is creating a new generation of millet entrepreneurs who are driving innovation, creating employment opportunities and contributing to the overall growth of the millet industry.
- To further support budding entrepreneurs and turn innovative ideas into successful businesses, Nutrihub offers comprehensive incubation services and grant-in-aid programmes. These initiatives provide crucial support to new businesses, helping them navigate the challenges of the millet industry and establish sustainable enterprises.
- The incubation programme provides startups with: (a) access to office space and shared processing facilities (physical infrastructure); (b) guidance from ICAR-IIMR scientists and industry experts (technical support); (c) assistance in refining business models and growth strategies (business mentoring); (d) connections with potential partners, suppliers and customers (networking opportunities); and, (e) support in navigating food safety regulations and certification processes (regulatory guidance).
- The grant-in-aid programme offers financial support to promising startups, helping them overcome initial funding challenges. This financial assistance is often crucial in the early stages of product development, market testing and scaling up operations.

Through these comprehensive efforts in production, procurement, processing and value addition, Nutrihub is playing a pivotal role in transforming the millet sector. By addressing challenges at various stages of the value chain and fostering innovation and entrepreneurship, Nutrihub is contributing significantly to the revitalisation of millet cultivation, processing and consumption in the country. These initiatives are

not only enhancing farmer incomes and creating new business opportunities for them, but are also contributing to improved nutrition and food security across the country.

10.3 R&D Efforts on Bridging Critical Gaps

10.3.1 Establishment of the Centre of Excellence on Millets

Nutrihub has made a significant stride in advancing millet research and development by establishing the Centre of Excellence on Millets. This specialised center serves as a focal point for comprehensive R&D support to startups and established businesses in the millet sector. The centre brings together a multidisciplinary team of researchers, food technologists and industry experts to address the critical challenges facing the millet industry. The Centre of Excellence is equipped with state-of-the-art facilities for millet research, product development and quality testing. It provides a collaborative environment where academic research meets practical industry needs, fostering innovation and problem solving in the millet sector. By offering tailored support to startups, the centre plays a crucial role in bridging the gap between laboratory research and commercial application, accelerating the pace of innovation in the millet industry.

10.3.2 Addressing Crucial Gaps in Millet Processing and Value Addition

Recognising the critical challenges hindering the growth of millet sector, Nutrihub has focused its R&D efforts on addressing several key areas, such as:

- Low efficiency in processing: The centre has conducted extensive research to improve the efficiency of millet processing. This includes developing and optimising processing techniques that are specifically tailored to different millet varieties. The research has led to the design of more efficient de-hulling, milling and sorting processes, significantly reducing processing time and energy consumption while improving the quality of the final product.

- Lower shelf life: A major focus of the R&D efforts has been on extending the shelf life of millet products. Researchers at the centre have investigated various factors affecting the shelf life of millet-based foods, including moisture content, packaging materials and storage conditions. Through these studies, innovative preservation techniques and packaging solutions have been developed that significantly enhance the stability and longevity of millet products.

- Inadequate branding and labelling: Recognising the importance of effective marketing in promoting millet consumption, the centre has conducted consumer research and market studies to understand packaging preferences and effective labelling strategies. Research has guided the development of appealing and informative packaging designs that effectively communicate the nutritional benefits and quality of millet products to consumers.

- Lack of knowledge on safety and quality control: The Centre of Excellence has developed comprehensive quality control protocols and safety standards specifically for millet processing and products. These guidelines cover all aspects of the production chain, from raw material selection to final product testing. The centre also conducts regular training programmes for industry professionals on implementing these safety and quality control measures and ensuring that high standards are maintained across the sector.

- Novel product development for new age consumers: Understanding the evolving preferences of modern consumers, Nutrihub has placed a strong emphasis on developing innovative millet-based products. The R&D team at the Centre of Excellence has worked on creating a wide range of novel products that cater to various consumer segments:

- Development of ready-to-eat and easy-to-prepare millet-based products that align with the fast paced lifestyle of urban consumers.

- Creation of functional foods and nutraceuticals that leverage the nutritional benefits of millets, catering to health conscious consumers.

- Formulation of premium millet-based ingredients and products for the culinary industry, expanding the use of millets in fine dining and gourmet cooking.

- Development of nutrient rich, appealing millet-based foods specifically designed for children, addressing both nutritional needs and taste preferences that can be included in ICDS programmes.

- The centre not only focuses on product development but also provides support to startups in scaling up these innovations. This includes assistance in process optimisation for large-scale production, guidance on regulatory compliance and support in market testing and product launches.

10.3.3 Enhanced Shelf Life through Innovative Techniques

One of the most significant achievements of Nutrihub's R&D efforts has been the dramatic improvement in the shelf life of millet products. Through innovative research and the application of advanced food preservation techniques, the centre has developed millet products with extended shelf life. For many of the developed products, researchers have successfully achieved a shelf life of up to nine months. In some cases, the R&D team has pushed the boundaries even further, achieving a remarkable shelf life of up to 12 months for certain millet products. This extended shelf life has been accomplished through a combination of methods and processes. These advancements in shelf life extension have significant implications for the millet industry, such as:

- Improved market reach: Products can be distributed over a wider geographical area, including export markets, without compromising on quality.
- Reduced waste: Extended shelf life means less product spoilage, contributing to more sustainable food systems.
- Enhanced consumer confidence: Longer lasting products provide assurance of quality and freshness to consumers, that may potentially lead to repeated purchases.

Through these comprehensive R&D efforts, Nutrihub has made substantial progress in addressing critical gaps in the millet sector. By improving processing efficiency, extending product shelf life, enhancing branding and labelling, and developing novel products, the Centre of Excellence on Millets is playing a pivotal role in modernising the millet industry and increasing its competitiveness in the global food market. These innovations are not only benefiting startups and established businesses but are also contributing to the wider goal of promoting millet consumption and improving nutritional security.

10.4 Enabling Market Linkages

Nutrihub's efforts in enabling market linkages have been instrumental in creating a robust ecosystem for millet-based businesses, particularly startups. These initiatives have focused on three key areas: connecting start-ups with captive markets, facilitating industry partnerships for scaling up production, and mainstreaming millets through public funded programmes.

10.4.1 Connecting Startups with Captive Markets

Nutrihub has recognised that one of the biggest challenges faced by millet startups is accessing reliable and consistent markets for their products. To address this, the institute has developed a comprehensive strategy to connect these emerging businesses with captive markets.

10.4.2 Institutional Partnerships

Nutrihub has fostered relationships with various institutions such as schools, colleges, corporate cafeterias and government organisations. These partnerships create dedicated channels for millet products, providing startups with stable, high volume customers. For instance, collaborations with school meal programmes have introduced millet-based items into children's diets while offering a reliable market for startups.

10.4.3 Retail Chain Collaborations

By leveraging its industry connections, Nutrihub has facilitated partnerships between millet startups and major retail chains including giants like Lulu. This has enabled these startups to place their products on the shelves of supermarkets and specialty stores, significantly expanding their consumer reach.

10.4.4 E-commerce Platforms

Recognising the growing importance of online retail, Nutrihub has assisted startups in establishing their presence on various e-commerce platforms. This digital market linkage has allowed millet businesses to reach a nationwide customer base, overcoming geographical limitations.

10.4.5 Food Service Industry Connections

Nutrihub has worked on creating linkages between millet startups and the food service industry, including restaurants, hotels and catering services. This has opened up new avenues for millet products in the hospitality sector, driving both innovation and demand.

10.4.6 Export Market Facilitation

For startups with export potential, Nutrihub has provided guidance on international market entry, including assistance with regulatory compliance and connecting them with foreign distributors and importers. As millet startups grow and their

products gain traction in the market, scaling up production becomes a critical need. Nutrihub has played a pivotal role in facilitating the growth by linking startups with established industry players.

10.5 Technology Transfer

By facilitating technology transfer agreements between startups and established manufacturers, Nutrihub has enabled the scaling up of innovative millet products while maintaining quality standards.

10.6 Supply Chain Integration

Nutrihub has assisted in integrating millet startups into the supply chains of large food companies. This not only provides a market for the startups' products but also exposes them to industry standard practices and quality control measures.

10.7 Investment Facilitation

Nutrihub has organised networking events and investor meets, connecting promising millet startups with venture capitalists and angel investors interested in the food sector. This has helped startups secure the necessary funding for scaling up their operations.

10.8 Mainstreaming through Public Funded Programmes

Recognising the potential of public sector support in promoting millet consumption and supporting millet-based businesses, Nutrihub has been actively working on mainstreaming millets through various public funded programmes:

10.8.1 Integration with Government Nutrition Schemes

Nutrihub has advocated and facilitated the inclusion of millet-based products in government nutrition programmes such as the mid-day meal scheme and the ICDS. This not only creates a large and stable market for millet products, but also contributes to improving nutritional outcomes.

10.8.2 PDS Inclusion

Working with policymakers, Nutrihub has supported initiatives to include millets in the PDS. This significant step has created a vast market for millet producers and processors, making these nutritious grains more accessible to the general population.

10.8.3 Armed Forces and Paramilitary Canteens

Nutrihub has facilitated the introduction of millet-based products in the canteens of armed forces and paramilitary organisations. This initiative not only provides a captive market for millet startups, but also promotes the nutritional benefits of millets among service personnel.

10.8.4 Government Procurement Policies

Nutrihub has been instrumental in advocating for the inclusion of millet-based products in government procurement policies. This has opened up opportunities for millet startups to participate in tenders for supplying to government institutions and events.

10.9 Research and Development Grants

By liaising with various government departments and research funding agencies, Nutrihub has helped secure R&D grants for millet focused projects. These grants have supported startups in product development and innovation, further driving the growth of the millet industry.

10.9.1 Skill Development Programmes

Nutrihub has collaborated with government skill development initiatives to create training programmes focused on millet processing and product development. These programmes not only create a skilled workforce for the millet industry, but also promote entrepreneurship in this sector. Through these comprehensive efforts in enabling market linkages, Nutrihub has created a supportive ecosystem for millet startups and businesses. By connecting these companies with captive markets, facilitating industry partnerships for scaling up and leveraging public funded programmes, Nutrihub has significantly contributed to the growth and sustainability of the millet sector. These initiatives have not only benefited individual businesses, but have also played a crucial role in increasing the overall consumption and acceptance of millets in India, contributing to both economic development and nutritional security.

10.10 Positioning Millets in Global Markets

Nutrihub's efforts to position millets in global markets have been multifaceted and strategic, focusing on collaboration with key export bodies, development of ex-

port-specific products, and providing support to startups in navigating international trade requirements. These initiatives have significantly contributed to enhancing the global presence of Indian millets and millet-based products.

10.10.1 Collaboration with APEDA for Global Promotion

Nutrihub has established a crucial partnership with APEDA to promote millets in international markets:

- Joint promotional activities: In collaboration with APEDA, Nutrihub has participated in international food expos, trade fairs and exhibitions. These events have provided platforms to showcase the diversity and quality of Indian millet products to a global audience. Notable exhibitions include SIAL Paris, Anuga in Germany and Gulfood in Dubai, where Indian millet products have garnered significant interest.

- Buyer-seller meets: Nutrihub has organised buyer-seller meets with APEDA and other state governments at different events. These events have facilitated direct interactions between Indian millet startups and international buyers, leading to business relationships and export opportunities.

- Market research and intelligence: Leveraging APEDA's extensive network and market intelligence, Nutrihub has gained insights into global millet consumption trends, regulatory requirements in different countries and potential market opportunities. This information has been invaluable in guiding startups towards promising export markets.

- Capacity building for export: In partnership with APEDA, Nutrihub has conducted workshops and training programmes for startups on various aspects of exporting, including documentation, quality standards and international marketing strategies specific to the food sector.

- Creation of export-specific products: Recognising that different international markets have unique preferences and requirements, Nutrihub has focused on developing export-specific millet products.

- Market-specific product development: Nutrihub has conducted extensive research on dietary preferences, taste profiles and culinary traditions of major

export destinations. Based on this research, they have developed millet-based products tailored to specific markets. For example, millet-based pasta for the Italian market, millet snacks with Mediterranean flavors for Middle Eastern countries, and gluten-free millet breads for health conscious consumers in North America and Europe.

- Packaging and labeling customisation: Working closely with startups, Nutrihub has developed packaging and labeling solutions that comply with the regulatory requirements of different countries while also appealing to local consumers. This includes multilingual packaging, country-specific nutritional information formats and culturally appropriate branding.

- Shelf life enhancement for long distance transport: Given the challenges of long distance transportation in international trade, Nutrihub has focused on developing preservation techniques and packaging solutions that extend the shelf life of millet products without compromising on quality or nutritional value. This has been crucial in ensuring that products remain fresh and appealing upon reaching international markets.

- Functional food development: Capitalising on the growing global trend of functional foods, Nutrihub has supported the development of millet-based products with enhanced nutritional profiles or specific health benefits. These products are particularly aimed at health conscious consumers in developed markets.

- Ready-to-eat and convenience products: Recognising the global demand for convenience foods, Nutrihub has assisted in the development of ready-to-eat millet products that cater to busy lifestyles while offering nutritional benefits. These include instant millet meals, millet-based breakfast cereals, and snack bars.

- Support for startups in export licensing and certification: To enable startups to participate effectively in export markets, Nutrihub has provided comprehensive support in navigating the complex landscape of international trade regulations.

- Export licensing guidance: Nutrihub has offered step-by-step guidance to startups on obtaining necessary export licenses. This includes assistance in preparing documentation, liaising with relevant government departments and ensuring compliance with export regulations.

- Compliance with international food safety standards: Nutrihub has made attempts to help startups comply with international food safety standards such as the FDA regulations for the US market and the EU food safety norms. This includes training on good manufacturing practices (GMP) and implementation of food safety management systems.

- Intellectual property rights protection: To safeguard the innovations of millet startups in international markets, Nutrihub has provided guidance on intellectual property protection, including assistance with international trademark registration and patenting of novel millet-based products or processes.

- Export documentation training: Nutrihub has conducted workshops on export documentation, covering aspects such as commercial invoices, certificates of origin, phytosanitary certificates and other documents required for international trade in food products.

- Market-specific regulatory compliance: Understanding that different markets have varying regulatory requirements, Nutrihub has provided tailored support to startups in meeting the specific regulations of their target export destinations. This includes guidance on labeling requirements, permitted ingredients and marketing claims allowed in different countries.

Through these comprehensive efforts in positioning millets in global markets, Nutrihub has played a pivotal role in elevating Indian millets to the international stage. By collaborating with APEDA for promotional activities, developing export-specific products and providing crucial support in export licensing and certification, Nutrihub has significantly enhanced the export readiness of millet startups. These initiatives have not only opened up new markets for Indian millet products but have also contributed to establishing India as a key player in the global millet trade. The success of these efforts is reflected in the growing international recognition of Indian millets as nutritious, versatile and sustainably produced superfoods, paving the way for continued growth and innovation in the sector.

10.11 Transfer of Technologies

Nutrihub has made significant strides in transferring cutting edge technologies to the millet industry. One of their most impactful initiatives has been the successful transfer of technologies developed at the Centre of Excellence to more than 250 start-

ups. This large-scale technology transfer has played a crucial role in fostering innovation and entrepreneurship within the millet sector. By providing these startups with access to advanced technologies, Nutrihub has not only contributed to the growth of the millet industry, but has also facilitated the creation of new job opportunities. This initiative demonstrates Nutrihub's commitment to nurturing a vibrant ecosystem of millet-based enterprises and boosting the sector's overall development.

10.11.1 Knowledge Partnership with Industry

In an effort to expedite product development and marketing processes in the millet industry, Nutrihub has established a valuable knowledge partnership with Nestle, a global leader in the food and beverage sector. This collaboration exemplifies Nutrihub's strategy of leveraging industry partnerships to accelerate the integration of millets into mainstream food products. By sharing their expertise, research findings and technological innovations with Nestle, Nutrihub is helping to bridge the gap between scientific research and commercial application. This partnership not only benefits Nestle, but also sets a precedent for future collaborations between research institutions and industry leaders in the food sector.

10.12 Collaborative R&D Support for Millet Value Addition

Recognising the importance of value addition in promoting millet consumption, Nutrihub has forged strategic collaborations with major food companies such as PepsiCo, ITC and Britannia. These partnerships are focused on supporting R&D efforts in millet value addition. By working closely with these companies, Nutrihub is able to influence and enhance the development of millet-based products on a large scale. This collaborative approach ensures that the latest research findings and technological advancements in millet science are effectively translated into innovative and marketable products. Furthermore, these partnerships help in aligning research priorities with market demands, that may promote wider acceptance and consumption of millet-based products among consumers.

10.13 Market Intelligence

Comprehensive industry assessment of millet products by Nutrihub has demonstrated its commitment to understanding and shaping the millet market. This assessment focused on mapping millet products across various categories, providing valuable insights into the current state and future potential of the millet industry. By

conducting this comprehensive evaluation, Nutrihub has created a detailed landscape of millet-based products available in the market, their positioning and consumer acceptance. The insights gained from this assessment are invaluable for policymakers, entrepreneurs and established companies alike. They can use this information to align their strategies with market demands, identify potential areas for investment, and develop products that cater to evolving consumer needs. This initiative by Nutrihub exemplifies its role not only as a research institution, but also as a key player in driving market oriented growth in the millet sector.

Recognising the international potential of millet-based products, Nutrihub has taken a proactive approach in exploring global markets. The organisation has conducted a comprehensive mapping of potential export destinations for millet value-added products. This strategic initiative demonstrates Nutrihub's vision of positioning Indian millet products on the global stage and tapping into international markets. The mapping exercise involved a detailed analysis of various international markets, consumer preferences, dietary habits, regulatory environments, and market penetration of similar products. By identifying promising export destinations, Nutrihub has laid the groundwork for Indian millet producers and processors to expand their reach beyond domestic markets. This global market intelligence provides several benefits to the Indian millet industry. It helps exporters to target the most receptive markets, for increasing export volumes and value. Additionally, understanding international market requirements can guide product development and adaptation efforts, ensuring that Indian millet products meet global standards and preferences. This initiative also aligns with the government's goal of promoting millets as 'nutri-cereals' and establishing India as a global hub for millets.

By providing this crucial market intelligence, Nutrihub is not only supporting individual businesses, but also contributing to the overall growth of India's millet export sector. This effort has the potential to enhance the country's agricultural export portfolio and reinforce India's position as a key player in the global health food market.

10.14 Institutional Support

10.14.1 Empowering Stakeholders (FPOs, SHGs and Startups) across different States

Nutrihub has played a pivotal role in supporting state millet missions by empowering grassroots organisations across India. The organisation has focused on

strengthening SHGs and FPOs in several states, including Andhra Pradesh, Arunachal Pradesh, Karnataka, Maharashtra and Odisha. This initiative has been crucial in creating a robust foundation for millet cultivation, processing and marketing at the local level. By empowering these community-based organisations, Nutrihub has helped to create a sustainable ecosystem for millet production and consumption. This support has enabled farmers to pool resources, share knowledge, and gain better access to markets, thereby, improving their economic prospects. Furthermore, the empowerment of SHGs and FPOs has contributed towards rural development in these states, aligning with the broader goals of poverty alleviation and sustainable agriculture.

10.14.2 State Specific Technological Support for Millet Promotion

Nutrihub has demonstrated its commitment to promoting millets by providing tailored technological support to various states, considering their unique agro-climatic conditions and developmental needs.

- Kerala – introducing millet cultivars in new areas: In Kerala, Nutrihub has offered technological backstopping for introducing millet cultivars in new areas. This support has been crucial in expanding millet cultivation to regions, where it was not traditionally grown. By considering the specific agro-climatic conditions of Kerala, Nutrihub has ensured that the introduced millet varieties are well-suited to the local environment, thereby, increasing the chances of successful adoption by farmers.
- Odisha – advancing millet value addition: In Odisha, Nutrihub has provided technological support focused on millet value addition. This initiative has been instrumental in diversifying the range of millet-based products available in the market. By introducing new processing technologies and product development techniques, Nutrihub has helped create new market opportunities for millet farmers and processors in the state.
- Uttarakhand – developing an integrated millet value chain: Nutrihub has assisted Uttarakhand in the technological aspects of developing an integrated millet value chain. This comprehensive approach encompasses various stages from cultivation to marketing, contributing significantly to the state's efforts to establish a millet food park. The expertise provided by Nutrihub has been crucial in ensuring that each component of the value chain is technologically sound and efficiently integrated.

- Chhattisgarh – establishing millet processing facilities: In Chhattisgarh, Nutrihub has been actively involved in creating millet processing facilities. This initiative is vital for adding value to raw millet produce and creating a variety of millet-based products. By supporting the establishment of these facilities, Nutrihub is helping to create local employment opportunities and boost the millet-based economy in the state.
- Karnataka – building market linkages and international exposure: Nutrihub has provided multifaceted support to Karnataka's state millet mission. The organisation has been instrumental in building market linkages through startups, fostering innovation and entrepreneurship in the millet sector. Additionally, Nutrihub has assisted in organising international trade fairs on millets and organics. These events have been crucial in showcasing Karnataka's millet products to a global audience, potentially opening up new export opportunities for the state's millet producers.

10.14.3 Supporting National and International Millet Initiatives

Nutrihub has played a significant role in supporting the Department of Agriculture and Farmers Welfare in successfully organising the IYM 2023. This global initiative aimed to raise awareness about the nutritional benefits of millets and promote their cultivation and consumption worldwide. Nutrihub's involvement in this campaign demonstrates its commitment to promoting millets on a global scale. As part of this support, Nutrihub has facilitated awareness and promotion by organising several national and international events. These events have served as platforms for knowledge sharing, networking and showcasing the latest developments in millet research, cultivation and product development. By bringing together stakeholders from various sectors and countries, these events have contributed significantly to the global recognition of millets as a nutritious and sustainable food source.

Through these initiatives, Nutrihub has demonstrated its crucial role in advancing the millet sector at both national and international levels. The organisation's multifaceted approach, combining technological support, market development and policy advocacy, has been instrumental in positioning India as a global leader in millet research and promotion.

11. Way Forward

As Nutrihub continues its pivotal role in advancing the millet sector, several key areas have been identified for future focus and development. This comprehensive strategy aims to strengthen the entire millet value chain, from production to market positioning, ensuring sustainable growth and global competitiveness.

11.1 Expanding Production and Enhancing Procurement

To boost millet cultivation, particularly in non-traditional areas, Nutrihub proposes a two-pronged approach. One, the implementation of incentive programmes to encourage farmers in these regions to adopt millet cultivation. This could include financial subsidies, technical support and guaranteed procurement at favorable prices. Secondly, strengthening of existing seed hubs and development of robust backward linkages with FPOs is crucial. This will ensure consistent and high quality seed supply, addressing one of the fundamental requirements for expanding millet cultivation.

11.2 Advancing Processing and Value Addition

The future of the millet industry lies in diversifying value-added products to garner higher prices and increase farmer profits. Nutrihub recommends exploring advanced processing technologies to achieve this goal. The focus will be on developing new ready-to-eat (RTE), ready-to- cook (RTC) and ready-to-serve (RTS) products using cutting edge techniques. This includes incorporating prebiotics and probiotics, creating composite foods, and developing milk and meat analogues from millets. These innovations will not only cater to evolving consumer preferences, but also open up new market segments for millet-based products.

11.3 Intensifying R&D Efforts to Address Critical Gaps

Nutrihub has identified several critical areas for R&D. Improving primary processing machinery is a top priority, with the goal of increasing efficiency from the current 60% to 80%. This advancement will significantly reduce post-harvest losses and improve the quality of millet grains available for further processing. Additionally, efforts will be directed towards scaling up secondary processing technologies and establishing standardised degrees of polishing for different millet varieties. Another crucial area of focus is extending the shelf life of millet products from the current nine months to 12 months through shelf life studies and improved packaging technologies.

11.4 Strengthening Market Linkages

Ensuring that farmers have access to high-quality seeds, competitive prices and reliable markets is essential for the sustainable growth of the millet sector. Nutrihub proposes to facilitate this by linking startups with captive markets, including public funded programmes (business-to-government or B2G) and industry partnerships (business-to-business or B2B). This approach will create a stable demand for millet products, providing farmers with assured markets and fair prices for their produce.

11.5 Positioning Millets in Global Markets

To enhance India's position in the global millet market, Nutrihub suggests building export-specific production clusters and positioning 2-3 selected millet varieties as champion millets. This targeted approach will help in creating a strong brand identity for Indian millets in the international market. To facilitate easier trade and better tracking of millet exports, the allocation of separate HS (Harmonized System) codes for all millet products is recommended. Furthermore, the creation of an export promotional forum will provide the necessary institutional support to boost millet exports.

11.6 Enhancing Technology Transfer

Nutrihub aims to strengthen the global value chain for millets by transferring processing technologies to other nations through SSTC. This international transfer of technologies will not only help in expanding the global millet market, but also position India as a leader in millet research and technology. Domestically, the focus will be on joint R&D projects, coupled with incubation and accelerated support for millet startups. Encouraging private investments in these startups will provide the necessary financial backing for rapid growth and innovation.

11.7 Improving Market Intelligence

To guide strategic decisions and market entry, Nutrihub proposes comprehensive mapping of countries for potential trade and exports. This will involve analysing export competitiveness to build a product portfolio with appropriate marketing and branding strategies. The organisation will focus on analysing markets and promoting targeted exports, particularly aligned with major importers such as China, Japan, Kenya, Belgium and Italy. This data driven approach will ensure that Indian millet products are tailored to meet the specific demands of these key markets.

11.8 Advocating for Supportive Policies

Mainstreaming millets through price, market and institutional support remains a key objective. Nutrihub will advocate for the inclusion of millets in government nutrition programmes such as the ICDS and mid-day meal schemes. This would not only provide a stable market for millet producers, but also contribute to improving nutrition at a national level. Additionally, the organisation will push for incentivised cultivation alongside committed procurement as per MSP, thereby, ensuring fair returns for millet farmers.

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About The Author

Dr. B. Dayakar Rao is Ex-CEO Nutrihub and Principal Scientist (Retd) at ICAR-Indian Institute of Millets Research. He is a renowned researcher in the millet ecosystem, with over 32 years of experience in building a science-based millet value chain in India. His work focuses on bridging the gap between farmers and consumers by addressing critical issues in nutrition, processing, mechanisation, entrepreneurship development, and policy advocacy. Dr. Dayakar has successfully replicated a successful millet value chain model across various Indian states, including Karnataka, Odisha, Chhattisgarh, Telangana, Andhra Pradesh, Rajasthan, Madhya Pradesh, and Uttarakhand.

Dr. Dayakar has published over 80 publications in national and international journals, including research papers, books and book chapters. He has collaborated with industry and international institutions to strengthen the efforts for mainstreaming millets and scaling up the R&D efforts. He has developed more than 80 value-added technologies and over 500 national and international recipes. He has been instrumental in establishing the Centre of Excellence on Millets for dedicated research on millet value addition and Nutrihub, a Technology Business Incubator (TBI) hosted at ICAR-IIMR, an institution providing a holistic support to millet start-ups in the country.

Dr. Dayakar has guided over 400 startups and entrepreneurs, incubated over 250 and facilitated financial grants to more than 110 startups to the tune of ₹10.5 crore. He has also facilitated the transfer of technologies to more than 300 startups and entrepreneurs. His achievements have been recognised through several awards, including the Innovative Scientist National Award under the SIRIDHANYA-Millet Award in 2018 and 2023, Best Incubator in Food Sector Award in 2021, Leader with a Strategic Vision' award 2023, Leadership in Business Excellence 2025 and has been recognized for his immense contributions to the innovation and startup ecosystem by Confederation of Women Entrepreneurs (CoWE). Dr. Dayakar has served as the chairman and member of different task forces by Government of India for International Year of Millets 2023 and also contributed to promotional efforts of Government of India by being the member of core committee on International Year of Millets 2023, chaired by the cabinet secretary.

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