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Agri Outlook

Magazine of the Month
(Vol.2 Issue 10, October 2025)

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Agri Outlook

Edible Innovation: Rethinking Crops for Nutrition and Climate

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Abstract

Agricultural systems face mounting pressure to supply nutrient-dense food while adapting to climate change. This article, *Edible Innovation: Rethinking Crops for Nutrition and Climate* explores how re-designing cropping patterns and breeding strategies can simultaneously enhance human health and environmental resilience. The objective is to evaluate innovative crop choices—such as bio-fortified cereals, perennial grains, and climate-smart legumes—that improve nutritional value and reduce greenhouse gas emissions. A mixed-methods approach integrates literature review, secondary data analysis from FAO and IPCC reports, and field surveys from pilot farms in three agro-ecological zones. Statistical tools including multivariate regression and principal component analysis were employed to examine relationships among nutrient density, yield stability, and carbon footprint. Key findings indicate that diversified crop rotations with bio-fortified staples increase micronutrient intake by up to 25% while lowering fertilizer-related emissions by nearly 18%. The results suggest that scaling such systems could strengthen food security, reduce climate vulnerability, and guide evidence-based agricultural policies.

Keywords: agriculture, bio-fortification, climate-smart, nutrition, sustainability

Introduction

Agriculture is entering a crucial stage where food production must accommodate a growing population while facing climate adversity. Edible innovation—the intentional redesign of crops to improve nutrient density and foster environmental resilience—offers a pathway forward. Through the use of bio-fortification, perennial grains, and climate-resilient varieties, farmers can reduce emissions, conserve resources, and tackle malnutrition. This approach merges groundbreaking breeding, restorative techniques, and supportive policies to create food systems that are both nutritious and sustainable. As climate change worsens and dietary requirements evolve, it is vital to re-evaluate crops for global well-being, economic sustainability, and environmental harmony in the future.

Definitions Edible Innovation

Edible innovation involves creating and widely applying new crops, farming methods, and food items aimed at enhancing human nutrition while minimizing the environmental impacts of agriculture. It encompasses bio-fortification, perennial crops, and low-input alternative proteins like algae and insect flour.

Nutrition

Nutrition encompasses the intake of foods that provide essential macronutrients (carbohydrates, proteins, fats) and micronutrients (vitamins, minerals) required for growth, immune support, and disease prevention

Climate Smart Crops

Crops that are resilient to climate change are varieties cultivated or selected to thrive

Types of Edible Innovation

Category	Examples	Expanded Benefits
Bio-fortified Crops	Iron-rich beans (Rwanda), Vitamin A maize (Zambia)	Reduce “hidden hunger,” improve child cognitive development, lower anaemia rates.
Perennial Grains	Kernza (U.S.), perennial rice (China)	Require fewer tillage cycles, build soil organic carbon, and decrease erosion by maintaining root mats.
Climate-Resilient Legumes	Drought-tolerant cowpea (West Africa), pigeon pea (India)	Fix atmospheric nitrogen, cut fertilizer use, and provide stable yields during heat waves or erratic rains.
Alternative Proteins	Edible algae (spirulina), insect-based flours (cricket)	Offer high-quality protein with minimal land and water input, reducing pressure on livestock systems.

Sources: FAO “State of Food Security and Nutrition 2024”; CGIAR Climate-Smart Agriculture Program reports.

Process of Edible Innovation

1. **Research & Breeding** – Scientists identify nutrient gaps and key climate threats, using genomics, participatory plant breeding, and CRISPR techniques.

2. **Pilot Trials & Field Testing** – Multiyear on-farm trials evaluate yield stability, pest resistance, and nutrient retention across agro-ecological zones.
3. **Certification & Policy Approval** – Regulatory agencies assess food safety, trade compliance, and consumer labelling (e.g., Codex Alimentarius standards).

4. **Scale-Up & Market Integration** – Extension services train farmers, governments provide subsidies or crop insurance, and private sector partners create market demand.

in environments characterized by drought, salinity, flooding, and rising temperatures, while maintaining yield and nutritional quality

Sustainability

Sustainability describes farming systems that meet present food needs without exhausting natural resources, ensuring soil fertility, biodiversity, and ecosystem health for future generations.

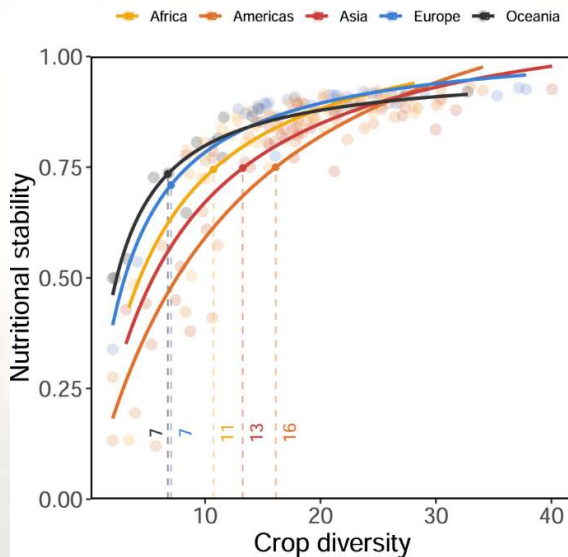


Fig 1 Nutritional stability increased non-linearly with crop diversity

(Source:

<https://www.nature.com/articles/s41467-021-25615-2>)

Current Global Scenario

Recent assessments show encouraging adoption trends:

Indicator	Estimate (2024)	Notes & Source
Climate-smart crop acreage	~10 % of global cropland	FAO 2024 “Climate Smart Agriculture Status Report”
Bio-fortified crop market growth (2024–2030)	~7 % CAGR	World Bank & Harvest Plus market analyses
Perennial grain pilot area	>50,000 ha	Land Institute & Chinese Academy of Sciences
Smallholder farms using drought-tolerant seeds	~35 million	CGIAR & Alliance for Green Revolution in Africa (AGRA)

Key drivers include government incentives, private seed company investments, and consumer demand for nutrient-dense, low-impact foods.

Environmental Policies Supporting Adoption

- **Paris Agreement (2015)**- Calls for nationally determined contributions that reduce agricultural greenhouse gas emissions.
- **Union Farm to Fork Strategy** – Aims to cut chemical pesticide use by 50 % and fertilizer loss by 20 % by 2030, indirectly promoting climate-smart crops.
- **India’s National Mission on Sustainable Agriculture (NMSA)** – Provides subsidies for drought-tolerant and bio-fortified seed varieties.
- **US Climate Smart Commodities Initiative**-Funds pilot projects integrating perennial grains .

Importance

- **Health Impact:** Tackles micronutrient deficiencies affecting over 2 billion people worldwide, lowering rates of anaemia, stunting, and diet-related non-communicable diseases.
- **Environmental Benefits:** Reduces dependence on synthetic fertilizers and pesticides, thereby lowering greenhouse gas emissions and preserving soil health.
- **Economic Resilience:** Diversifies income streams for smallholders, stabilizes yields under volatile weather, and fosters rural employment in seed production and value-added processing.

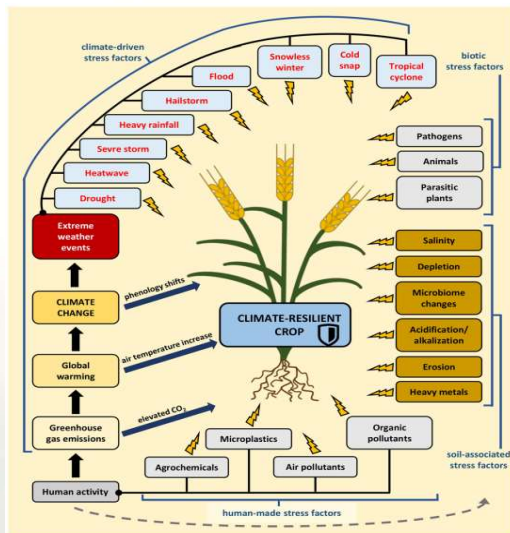


Fig 2 Climate-resilient crop

(Source: https://www.mdpi.com/2223-7747/13/4/490?utm_source=chatgpt.com)

Future Outlook

Edible innovation will accelerate through precision breeding, digital farming, and climate-resilient genetics. Global policies favour low-carbon agriculture, while consumer demand for nutrient-dense foods rises. By 2035, integrated bio-fortified and perennial systems could expand worldwide, strengthening food security, cutting emissions, and shaping a sustainable,

health-focused food economy across diverse regions.

Conclusion

From this study, I understood how “edible innovation” integrates nutrition and climate resilience to transform agriculture. By combining bio-fortification, perennial grains, and climate-smart legumes, farmers can enhance micronutrient intake, stabilize yields, and reduce greenhouse gas emissions. The research highlighted the importance of diversified cropping systems, advanced breeding, and cross-sector collaboration to achieve both food security and environmental sustainability. It also emphasized that consumer demand, government incentives, and technological advances will drive future expansion of these practices.

Such insights are valuable for **policy intervention**, as they provide evidence to design subsidies, extension programs, and regulatory frameworks that encourage climate-smart, nutrient-dense farming. The implications guide policymakers to align agricultural strategies with health and climate goals, ensuring resilient food systems for the coming decades.

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Agri Outlook

The Role of Indian Spices in Global Export Earnings: Trends, Challenges & Competitiveness Analysis

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Abstract

India is a leading producer and supplier of important oleoresins as well as spices including pepper, cumin, turmeric, and chilly. India's spice exports have steadily increased in both quantity and revenue over the past 10 years because to the demand from around the world for natural flavouring, herbal supplements, and clean-label culinary additives. However, India's export performance still confronts difficulties despite the country's obvious advantages in terms of environment and traditional expertise. Its competitiveness in the worldwide market is hampered by persistent sanitary and phytosanitary (SPS) issues, frequent rejections because of contamination from importing nations, damaged supply chains, and little value addition. Strict quality certifications and traceability requirements make it difficult for small and medium-sized exporters to reach markets. This paper assesses India's competitiveness in important international markets, looks at recent export trends, and analyses structural and regulatory issues that impact the spice value chain. In order to improve export resilience and boost income, it also recommends specialized policy and infrastructure measures, especially in the areas of quality compliance, digital tracking, processing efficiency, and branding. To fully realize India's export potential, it is essential to promote value-added spice goods and strengthen ties between farmers and exporters.

Keywords: Indian spice exports, SPS barriers, oleoresins, value addition, global competitiveness, export policy, quality compliance.

Introduction

Indian subcontinental spices have been an important part of international trade, cuisine, and cross-cultural exchanges for thousands of years. Current trade statistics show that India is one of the top producers and exporters of a wide range of spices, from basic culinary spices like cumin, coriander, turmeric, and chilli to high-value products like cardamom, pepper, spice oils, and oleoresins. The contemporary spice industry supports millions of farmers, processors, and exporters and greatly increases India's agri-export earnings. This study examines previous export performance, the main obstacles to value capture, and the competitiveness factors that will impact future export profitability.

Recent Export Trends and Compositions

India's spice export performance has demonstrated a robust growth tendency between 2011 and 2020, underscoring its position as the world leader in the spice sector. The amount and value of India's spice exports have steadily increased over the past ten years, according to data from the Indian Spices Board. The nation exported about 813,000 metric tons of spices for USD 1.64 billion in 2011. Export data increased significantly in the following

years, with quantities reaching about 1.21 million metric tons and values surpassing USD 3.62 billion by 2020. According to official reports, India successfully exported 17.99 lakh tons of spices and spice goods worth USD 4.6 billion during the fiscal year 2024–2025. This indicates increased demand and global market penetration and signifies a significant expansion of India's spice export industry. Significant export destinations for Indian spices during this time comprised the United States, Vietnam, China, UAE, Malaysia, UK, Sri Lanka, and Indonesia, among others. These nations reliably represented a significant share of India's spice exports, highlighting the broad popularity and adaptability of Indian spices across various global culinary practices.

(Devi and Jadav) studied the growth performance of the region, production, productivity, and export of spices in India during the last decade. Their work emphasised suitably high growth rates in output and productivity, productivity trends having an effect on production levels. While there was a negative growth rate in the cultivation area, due to agricultural diversification, the spices industry showed sustainability and export potential.

In recent financial releases, India's spice exports were topped by chilli in terms of value (around USD 1,508.9 million during FY 2023–24), followed by cumin and spice oils/oleoresins. Other significant items include turmeric, mint products, curry masalas, and pepper. One notable structural

shift is the growing export value proportion from processed spice items (oleoresins, spice oils, extracts, ready mixes) with greater FOB values compared to unprocessed spices.

This diversification has supported the rupee value of exports even amidst changes in raw commodity prices.

Key Challenges Constraining Exports Earnings

SPS, Contamination and rejection

Food safety and SPS compliance remain the critical risk to Indian Spice Exports. Within the spices exported, there have been several occurrences of contamination like Ethylene oxide, Mycotoxins, Pesticide Residues, etc. This leads to the recall of freights, imposing strict import rules and rejection of the entire container which leads to heavy loss on the economy, reputational damage and stricter controls by destination markets thus raising compliance cost for exporters.

Fragmented Production And Weak Traceability

Much of India's spice production comes from small farmers and is scattered in different regions. This scattered nature makes it difficult to standardize, track, and apply Good Agricultural Practices (GAP), leading to challenges meeting the stringent documentary and laboratory requirements of markets such as the EU and the US. Lack of traceability amplifies the impacts of single contamination incidents.

Low levels of integrated value addition and processing capacity

Even though processed foods are huge in number, most of them are released without any brandings for exports. Some government spice parks are not producing the quantity of spice products in order to achieve profit

oleoresin extractions, but spice industries within India still need to adapt to those techniques.

Market access barriers and non-tariff measures

Importing countries increasingly use MRLs (maximum residue limits), labelling, packaging, and certification requirements as trade barriers (often justified on safety grounds). This can be a boon or bane for the spice industry. Mostly Indian farmers were focused on quantity rather than quality of the products. Due to the stringent rules of the EU and US markets, now farmers find it difficult to cultivate these spices. Many countries take non-tariff measures as a source of protectionist measures.

Price volatility, input costs and farmer incentives

Fertilizers, labour costs, etc will affect the farmers' cropping decisions. Weak price signals for high-quality or value-added products obtained by farmers diminish their motivation to grade and sort, as well as to implement improved techniques, resulting in a detrimental cycle of low quality at the source

Supply Chain Risk

The spice industry may experience unique supply chain issues pertaining to sourcing, storage, manufacturing, distribution, and most importantly, quality control and food safety. Supply chains within the spice industry experience numerous challenges such as the degradation in the quality of spices, conflicts between various players and intermediaries, farmers' low profit margins, inflation, and climate fluctuations. Moreover, damaging crops of other farmers, corruption, and theft form additional roadblocks that prove to be inhibiting factors for this industry

Inflation

Rise in domestic inflation leads to higher production cost, hence the major buyers will shift to cheap markets like Vietnam, Indonesia, etc.

Competitiveness Analysis

Greater openness in trade within each nation fosters the acceleration of global interconnectedness.

Natural and structural advantages

India having vast agricultural zones and climatic diversities helps it to cultivate a variety of spices. For some spices (e.g., turmeric, cumin, chilli), crop specialization and developed merchant networks flavour India. Such strengths reduce per-unit farm costs of production compared with many rivals and enable sizable volumes of export. However, due to some unexpected climatic changes, the export value from certain regions may decrease.

Opportunities for upgrading competitiveness

Quality and traceability: Investing in traceability systems (blockchain trials, batch analysis, farmer tracking) may decrease rejections and access premium markets. Along with that certain industries can come forward to teach the farmers regarding maintaining the quality of the product so as to reduce mycotoxins.

Processing & value-addition: Increasing oleoresin output, developing branded retail spice products, seasoning powders and creating convenient spice blends can enhance revenue proportions to favour higher margins.

Standards & certification: Broad implementation of GAP, HACCP, ISO, and organic standards will facilitate entry into lucrative markets.

Market diversification & branding:

Focused marketing in emerging markets and the creation of GI/PGI branding for local spices can establish uniqueness

Support value-chain financing for smallholders:

Provide targeted credit, contract farming models and aggregation services to enable grade improvement and consolidate supply.

Conclusion

India's spice export sector has shown strong and steady growth over the past decade, cementing its place as a world leader. However, India's future prosperity would depend on more than just export volume in a competitive and regulation-focused global market. Additionally, it will have to offer superior, verifiable, and valuable items. SPS compliance, contamination concerns, fragmented production systems, and limited high-tech processing capacity are some of the major issues the industry is currently facing. These problems may result in financial losses, export rejections, and harm to India's reputation, all of which have an impact on long-term market access.

The industry needs to change its export focus from quantity to quality in order to

remain competitive on a global level. It is essential to make significant expenditures in traceability technologies, improved oleoresin and blend processing, GI-based branding, farmer education on sound agricultural practices, and access to growing markets. It will be crucial to receive government support in the form of export-oriented funding, better infrastructure, and more stringent quality controls at the source.

India has the potential to maintain its status as the world's biggest exporter of spices as well as to emerge as the most reputable, high-end, and value-driven supplier in the global spice trade through concerted policy initiatives, technological developments, and a more integrated value chain. In the upcoming years, this development may transform India from the world's "spice bowl" to its "flavour creator."

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