# India as a global manufacturing hub for smart protein processing equipment

*Key insights and strategic recommendations to build India's self-reliant smart protein equipment ecosystem*

**National Institute of Food Technology, Entrepreneurship and Management, Thanjavur (NIFTEM-T)**

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(An Institute of National Importance)

(राष्ट्रीय महत्व का संस्थान)

**Ministry of Food Processing Industries, Government of India**

खाद्य प्रसंस्करण उद्योग मंत्रालय, भारत सरकार

सत्यमेव जयते

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Director

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**Foreword**

It gives me great pleasure to present this report titled 'India as a Global Manufacturing Hub for Smart Protein Processing Equipment', prepared jointly by National Institute of Food Technology, Entrepreneurship and Management, Thanjavur (NIFTEM–T) and the Good Food Institute (GFI), India.

The rapid growth of alternative and smart protein sectors presents India with a unique opportunity to emerge as a global leader in advanced protein processing technologies. In this context, this study and the report hold special significance, as it systematically examines the status, capabilities, and future potential of indigenous manufacturing of critical processing equipment, key to the sector. The report focused attention on key equipment segments such as dryers, extruders, and separation systems, which form the backbone of smart protein production.

A major strength of this study lies in its robust methodology, involving extensive national-level primary data collection, supplemented by rigorous analysis of both primary and secondary data sources. The interactions with equipment manufacturers, startups, research institutions, and industry stakeholders have enabled the generation of practical, evidence-based insights. These findings provide a realistic assessment of technological gaps, investment needs, and policy interventions required to strengthen the ecosystem.

I sincerely appreciate the dedicated efforts of the research team from NIFTEM–T and GFI India in bringing out this comprehensive and forward-looking report. I am confident that the recommendations presented herein will serve as valuable inputs for policymakers, industry leaders, entrepreneurs, and researchers, and will contribute meaningfully towards positioning India as a global hub for smart protein processing equipment manufacturing.

I am certain that the recommendations of this report will be the foundation for a visionary transformation of the plant protein equipment manufacturing capabilities of India, paving the way for aligning with Government initiatives 'Make in India' and '*Atmanirbhar Bharat*'. I wish this report to be widely disseminated and impactful.

(Prof. V. Palanimuthu)

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**About the study partners**

**About the National Institute of Food Technology, Entrepreneurship and Management, Thanjavur**

National Institute of Food Technology, Entrepreneurship and Management, Thanjavur (NIFTEM-T) is an Institute of National Importance functioning under the aegis of the Ministry of Food Processing Industries, Government of India. NIFTEM-T has premier research and academic capabilities in the field of food technology and has been consistently ranked among the top agri- and allied-discipline institutions in the country. NIFTEM-T provides services to different segments of the food processing sector, spanning innovation, consultancy, incubation, quality testing, outreach, and awareness. The Institute offers BTech, MTech and PhD in Food Technology. With excellent national and international networking, the institute is open for collaborations and partnerships.

**About the Good Food Institute India**

The Good Food Institute India (GFI India) is a sector expert and convening organisation in the Indian alternative protein or smart protein sector in India. As part of an international network of organisations with partners in the U.S., Asia Pacific, Brazil, Europe, Israel, and Japan, GFI India works with a range of stakeholders towards a secure, sustainable, and just global food future. With unique insights across science, policy and industry, we are using the power of food innovation and markets to accelerate the transition of our food system toward smart proteins. In building the sector from the ground up in India, we're aiming to establish a model for its growth all across the developing world.

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**Industry stakeholders**

The authors acknowledge the participation of industry representatives across the smart protein equipment value chain, including process equipment manufacturers, component and subsystem suppliers, solution integrators, and technology providers. Their perspectives informed the assessment of current manufacturing capabilities, performance and reliability constraints, procurement and commissioning realities, and after-sales service considerations. The authors also acknowledge the support provided by said stakeholders to validate key assumptions and interpreting sectoral dynamics, including pathways for localisation, quality assurance, and export readiness.

**Academic and research experts**

The authors extend sincere appreciation to the academic and research professionals whose technical insights and domain expertise strengthened the analytical rigour of this report:

- Prof. H. N. Mishra, Emeritus Professor (Food Technology), Indian Institute of Technology Kharagpur
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**Disclaimer**

The findings and recommendations presented in this report are based on interviews and consultations with academic and industry stakeholders and reflect consensus across participants. All organisations that provided inputs have reviewed the representation of their contributions and provided consent for inclusion.

**Executive summary**

India is at a strategic inflection point to emerge as a global manufacturing hub for smart protein processing equipment. These capital goods enable the scalable production of plant protein isolates, concentrates, and plant-based alternatives to meat, eggs, dairy, and seafood. As global demand for these products rises, the need for specialised equipment like extruders, dryers, and separators will also rise. Building domestic manufacturing capacity in this segment aligns closely with national priorities under the Make in India initiative and the *Aatmanirbhar Bharat Abhiyan* mission. It offers India an opportunity to reduce import dependence, generate high-skill employment, strengthen industrial competitiveness, and integrate into global food technology value chains.

India already has strong foundational advantages that support this evolution. The country has a well-established food and process equipment manufacturing base, with an estimated 150 to 200 original equipment manufacturers serving food, dairy, chemicals, plastics, and allied sectors. These firms operate within established industrial clusters and benefit from dense supplier ecosystems. India's large pool of engineers and technicians, competitive manufacturing costs, and domestic availability of key inputs such as stainless steel, copper, polymers, motors, and electronics position domestic manufacturers to deliver reliable and cost-effective machinery at scale.

Despite these strengths, gaps constrain India's leadership potential in plant-based smart protein processing equipment. Domestic manufacturers currently focus on small- and mid-scale systems, while high-capacity and high-precision equipment such as high-moisture extruders, industrial spray dryers, and advanced membrane filtration units continue to be imported. Limitations in precision fabrication, advanced automation and control systems, and access to food-grade critical components remain, along with the absence of international standard testing and certification infrastructure. Limited R&D investment and fragmented industry-academia linkages further impact innovation. On the upside, stakeholders view these challenges as transitional and addressable, rather than as structural or binding constraints.

To unlock India's true potential as a global smart protein manufacturing leader, the report recommends a coordinated national strategy. Key actions include recognising plant-based smart protein processing equipment as strategic capital goods, integrating the sector into *Make in India* and relevant Production Linked Incentive (PLI) frameworks, establishing cluster-based common facility centres, harmonising standards with international norms, and strengthening public-private R&D and international technology partnerships.

With timely action, India can transition from a net importer to a globally competitive supplier, meeting domestic demand, expanding exports, and advancing national goals in advanced manufacturing, food security, and sustainability.

"Localisation of critical equipment in the smart protein manufacturing sector will ensure cost-effectiveness and higher productivity, leading to value-engineered products that can compete with leading brands the world over."

**-Mr. Ramesh T, Managing Partner, Borg**

**Table of contents**

**Glossary of terms**

| Term/Acronym | Explanation |
|---|---|
| **Smart proteins (globally known as alternative proteins)** | Products that can reliably and predictably diversify the consumption of animal-derived meat, eggs, and dairy because they replicate the sensorial and cultural experience and offer several advantages in the supply chain for producers. |
| **Plant-based smart protein** | The term refers to products which are solely made of ingredients derived from protein-rich crops such as pulses (pea, chickpea, mung bean), oilseeds (soy), cereals (wheat, rice), nuts (almond, cashew), and others (millets, jackfruit, potato). This category includes plant-based meat, eggs, dairy, and seafood that serve as alternatives to their corresponding animal-derived products. |
| **Extruder** | A processing machine that applies heat, pressure, and shear to ingredients, forcing them through a die to create structured food products. |
| **Twin-screw extruder** | An extruder using two intermeshing screws, offering superior mixing, shear control, and flexibility for protein texturisation. |
| **High-moisture extrusion (HME)** | An extrusion process in which feed materials using >50% moisture are processed to replicate the appearance and fibrous texture of conventional whole-muscle meat to produce the appearance and fibrous texture of whole-cut meat in plant-based meat products. |
| **Textured Vegetable Protein (TVP)** | A low-moisture extruded plant protein, typically soy-based, dried and later rehydrated for meat-like applications. |
| **Centrifuge** | A separator that uses centrifugal force to separate components of different densities in a mixture. |
| **Decanter centrifuge** | A continuous centrifuge that separates solids from liquids using a rotating horizontal bowl and internal screw conveyor. |
| **Membrane filtration** | A pressure-driven separation process using semi-permeable membranes to isolate proteins or remove impurities. |
| **Ultrafiltration** | Membrane filtration with fine pores in the typical size range of 0.01 and 0.1 microns, which retain proteins while allowing water and small molecules to pass through. |
| **Microfiltration** | Membrane filtration with larger pores in the size range of 0.1 to 10 µm, typically used to remove suspended solids, fats, or microbes. |
| **Spray dryer** | A dryer that converts liquid feed into powder by atomising it into hot air for rapid moisture evaporation. |

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|---|---|
| **Freeze dryer (Lyophiliser)** | A dryer that removes moisture by freezing the product and sublimating ice under vacuum, preserving structure and quality. |
| **Fluidised-bed dryer** | A dryer where hot air suspends particles in a fluid-like state, enabling uniform and efficient drying. |
| **Flash dryer** | A high-velocity dryer that rapidly removes surface moisture from fine particles using hot air streams. |
| **Supervisory Control and Data Acquisition (SCADA)** | A centralised system for real-time monitoring, data acquisition, and control of multiple industrial processes. |
| **Industry 4.0** | Advanced manufacturing approach integrating automation, data analytics, IoT, and digital control systems. |
| **Hygienic design** | Equipment design principles that minimise contamination risks and enable effective cleaning. |
| **European Hygienic Engineering & Design Group (EHEDG)** | A global consortium of food producers, equipment manufacturers, institutes and universities, providing guidelines for hygienic food equipment design. |
| **3-A Sanitary standards** | U.S.-based hygiene standards that ensure food equipment is cleanable and safe for food contact. |
| **Conformité Européenne (CE) Marking** | Certification indicating compliance with European Union safety, health, and environmental requirements. |
| **American Society of Mechanical Engineers (ASME) Standards** | Mechanical engineering standards that ensure safety and quality, particularly for pressure vessels and machinery. |
| **ISO certification** | International standards ensuring consistent quality, safety, and operational management systems. |
| **ISO G0.4 Dynamic Balancing** | A high-precision rotor balancing standard required for safe high-speed centrifuge and separator operation. |
| **Gearbox** | A mechanical system that converts motor speed into usable torque for heavy industrial equipment. |
| **Variable Frequency Drive** | A device that controls motor speed and torque by varying electrical frequency, improving efficiency. |
| **cGMP** | Current Good Manufacturing Practices that ensure hygienic, controlled, and compliant production environments. |
| **SS304, SS316** | Food-grade stainless steels widely used in equipment due to corrosion resistance and cleanability. |

| | |
|---|---|
| **High-Moisture Meat Analogue (HMMA)** | Plant-based meat products with high water content and fibrous structure, produced using high-moisture extrusion technology. |
| **Original Equipment Manufacturer (OEM)** | A company that designs and manufactures industrial equipment used by end-user industries. |
| **Compound Annual Growth Rate (CAGR)** | The annualised rate of growth over a period, assuming consistent compounding. |
| **Programmable Logic Controller (PLC)** | An industrial computer used to automate machinery operations by processing sensor inputs and controlling outputs. |
| **Human-Machine Interface (HMI)** | The visual interface that allows operators to monitor and control machines through screens or control panels. |
| **Internet of Things (IoT)** | Networked sensors and devices that collect and transmit operational data for monitoring and optimisation. |
| **Clean-In-Place (CIP)** | An automated cleaning system that cleans internal equipment surfaces without dismantling the machinery. |
| **Sterilise-In-Place (SIP)** | A process that sterilises equipment using heat or chemicals after cleaning, ensuring microbial safety. |
| **Computer Numerical Control (CNC)** | Automated machining technology that enables high-precision fabrication of mechanical components. |
| **Process Analytical Technology (PAT)** | Real-time analytical tools used to monitor and control manufacturing processes for consistent quality. |
| **Production-Linked Incentive (PLI)** | A government incentive scheme that rewards manufacturers based on incremental increases in production output over a period of time. |
| **Length-to-diameter ratio (L/D ratio)** | The ratio of screw length (L) to screw diameter (D) of the extruder. |
| **Emergency Credit Line Guarantee Scheme (ECLGS)** | Launched by the Government of India in May 2020 as part of the Aatmanirbhar Bharat Abhiyan, this scheme provides fully guaranteed, collateral-free, and low-cost credit to MSMEs and businesses to meet operational liabilities and restart businesses affected by the COVID-19 pandemic. |

# 1. Introduction and objectives

## 1.1. Background and rationale of the study

The global market for smart proteins is expanding rapidly, driven by a convergence of consumer preferences, environmental concerns, and investment trends. Among the different production platforms of smart proteins (plant-based, fermentation-derived and cultivated meat), the plant-based category is the most developed and easiest to produce at a large scale, particularly in emerging manufacturing markets. Moreover, plant-based diets are becoming increasingly popular for health, sustainability, and ethical reasons, prompting food companies to scale up production. The production of texturised plant proteins, protein powders, and meat alternatives involves protein isolation and structuring processes that warrant the use of extruders, dryers, and separators.

Extruders, particularly high-moisture twin-screw extruders, are well recognised for texturising plant proteins to mimic animal proteins. Separators, including filters, air classifiers, decanters, and centrifuges, are used for purifying and isolating protein extracts. Drying systems like spray dryers, flash dryers, fluidised-bed dryers, and freeze dryers are critical for making powdered protein isolates and concentrates, extending shelf life, and improving the convenience of storage and transport. India currently imports the majority of such high-end machinery. Although domestic manufacturers have built spray dryers and decanters since 1980, modern large-capacity dryers and membrane separators continue to be imported.

Manufacturing equipment influences outcomes in two fundamental ways. It shapes the economics of production by influencing capital cost, energy use, yield, maintenance intensity, and uptime. It also determines speed of scale through procurement lead times, commissioning cycles, and the availability of service and spares. When equipment is expensive, slow to deploy, or hard to maintain, manufacturers compensate by under-scaling plants, delaying expansions, or accepting higher operating costs. Each of these outcomes slows category growth and raises barriers for new entrants.

India has meaningful capability in process equipment manufacturing and a strong base of engineering talent and supplier ecosystems. However, advanced smart protein applications require precision fabrication, validated hygienic design, reliable controls, and consistent performance at scale. Where these capabilities remain incomplete, the market leans towards imported high-performance systems and imported critical subcomponents. The result is not only higher costs but also additional operational constraints that affect competitiveness.

This study has been designed to align with the nation's existing priorities and initiatives, including Make in India and Atmanirbhar Bharat. It assesses current technologies, identifies gaps in design and innovation, and evaluates indigenous manufacturing potential to guide policy and industry action for domestic equipment production. The findings show that enhancing domestic production capabilities, particularly in extruders, separators, and dryers, will be critical to reduce import reliance, reduce setup and operational costs, enable market entry for startups, attract global investments, generate high-skill employment opportunities, and position India as a potential exporter of next-generation food-processing machinery. Investing in building a robust smart protein equipment ecosystem can support long-term national goals of leadership in global capital goods value chains, increase the share of value addition in modern supply chains, and generate industrial employment while also improving nutritional security and climate resilience.

### 1.2. Objectives of the study

1. Conduct a comprehensive assessment of India's current manufacturing capabilities for plant-based smart protein processing equipment, with a focus on three equipment families that most directly determine the manufacturability of plant-protein ingredients and finished products: separators and filtration systems, dryers, and extruders.
2. Identify gaps in existing capabilities and evaluate opportunities to enable local production of cost-effective plant-based protein processing equipment.
3. Assess the interest, readiness, and key bottlenecks preventing global and domestic equipment manufacturers from entering India's plant-based smart protein processing equipment manufacturing sector.
4. Develop detailed, actionable recommendations for the government and private sector, highlighting the potential benefits of supporting this sector and outlining measures to create a favourable manufacturing ecosystem.

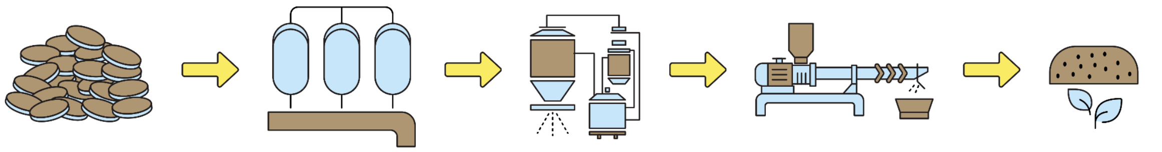



*Figure 1. Equipment-driven production flow for plant-based smart protein manufacturing*

## 2. Methodology

### 2.1. Scope of analysis

This study focuses on processing and post-processing equipment used in plant-based proteins and food processing, specifically:

- Extrusion: Twin-screw high- and low-moisture extruders
- Separation: Centrifuges, decanters, air classifiers and membrane filters (microfiltration, ultrafiltration)
- Drying: Spray, fluidised-bed, flash and freeze dryers

Upstream agricultural activities and downstream branding or retail activities (except where they directly drive equipment demand) are excluded from the scope of this study.

The analysis centres on India, with global benchmarks used to assess competitiveness and export opportunities.

### 2.2. Approach

The approach used in this study is a combination of secondary research, primary stakeholder engagement, and expert validation. The analysis was conducted in four sequential steps:

1. **Secondary research and data review** : A comprehensive review of trade statistics, policy documents, market reports, and prior studies by the Good Food Institute (GFI) was conducted. Import-export data by HS codes were analysed to quantify import dependence and identify priority areas for localisation (e.g., centrifuges under HS8421). Government publications and academic articles were used to benchmark equipment specifications, manufacturing capabilities, and supply chain capabilities.
2. **Equipment landscape mapping**: Domestic and global OEMs involved in extrusion, separation, and drying were profiled. This includes mapping equipment types, production capabilities, manufacturing locations, and areas of specialisation along with relevant industry associations.
3. **Primary stakeholder interviews:** Structured interviews using a questionnaire were conducted with 29 stakeholders across the ecosystem, including Indian OEMs, multinational equipment suppliers, component manufacturers, food processors, and academic experts. The focus of these interviews was to understand technology readiness levels, supply-chain patterns, cost structures, and bottlenecks in the system. Combining insights from primary and secondary data strengthens the reliability of the analysis. However, the findings should be interpreted as a comprehensive assessment rather than precise predictions.*
4. **Synthesis and triangulation:** Findings from primary interviews were cross-referenced with secondary data. Gaps and opportunities that emerged were analysed across four dimensions: technology, supply chain, policy, and workforce.

*Note: The views expressed by stakeholders represent prevailing industry perceptions at the time of the interviews and may change as the sector evolves.

## 3. Current manufacturing capabilities

India has approximately 150–200 OEMs involved in specified equipment manufacturing, particularly extruders, dryers, and separators. Many are traditional engineering firms repurposed from industries like plastics, chemicals, dairy, steel fabrication, and automotive parts.

> "Continued dependence on imports stems from inconsistent quality, limited availability of materials, manufacturing process variability, and constrained supplier capabilities, all of which increase uncertainty and risk in meeting desired product and equipment standards."
>
> **-Tetra Pak**

**3.1. Extruders**

International players dominate the premium and high-performance segments of the Indian extruder market. Advanced applications such as high-moisture extrusion and precision food-grade processing are primarily served by imported equipment. The domestic industry is highly fragmented, with many small and medium enterprises focusing on standard single-screw, twin-screw, and low- to mid-capacity machines, largely serving snack foods, textured vegetable protein (TVP), animal feed, and basic food-processing applications. Domestic industry is geographically concentrated, with NCR (Delhi-Gurugram-Faridabad) accounting for nearly 40% of domestic extruder manufacturers. Overall, competition is divided—domestic OEMs compete on cost, mechanical robustness and responsiveness, while global players retain a technological edge in terms of tight process control, hygiene compliance and consistent output quality. **India's extruder sector is highly import-intensive, not only at the system level but also at the component level. Stakeholder interviews indicate that 60–70% of control electronics, including PLCs, drives, relays, switches, and connectors, are imported. Even global OEMs manufacturing or assembling in India rely on imported precision components, keeping costs elevated.**

Despite competitive pricing—with Indian machines typically costing about half of European units—domestic machines do not match European-level precision or performance, particularly for food-grade and high-moisture applications.

Besides this, the extruder industry faces several structural constraints:

- Technology and precision gaps: Limited domestic R&D, testing infrastructure, and absence of hygiene-certification facilities (e.g., EHEDG-type labs).
- Supply chain dependence: Heavy reliance on imported electronics, gearboxes, and high-grade materials increases costs and lead times.
- Demand uncertainty: The domestic market for advanced extruders (e.g., high-moisture systems) remains small, discouraging OEM investment in R&D.
- Policy awareness and access: Many OEMs report limited awareness of, or difficulty accessing, existing government incentive schemes.
- Limited collaboration: Few joint ventures or structured technology-transfer arrangements exist to support capability upgrading.

**3.2. Dryers**

India has a well-established domestic base for spray and fluidised-bed dryers, driven historically by demand from the pharmaceutical, chemical, dairy, and spice-processing sectors. Some of this equipment could be repurposed for plant-based protein ingredients such as concentrates and isolates. While this base provides strong capabilities in small- to mid-scale drying systems, the market remains import-dependent for large-scale multi-effect dryers and industrial-scale freeze-dryers. Primary data from this study indicates that to meet requirements for large-capacity, fully automated, and food-grade compliant systems, a majority of the industrial freeze dryers are supplied by global OEMs, particularly from Germany and other European countries. However, this concentration is largely confined to the premium category. Indian manufacturers remain active in the broader market, especially in mid-range and application-specific segments, with some even competing with premium segments—demonstrating competitive capabilities in customisation, cost efficiency, and after-sales support.

Dryer manufacturing in India is concentrated in western industrial hubs. Maharashtra accounts for approximately 44% of dryer manufacturers, with Pune and Mumbai as important centres. Pune's advanced machining ecosystem—built on its automotive and aerospace legacy—supports high-quality fabrication and assembly. Gujarat hosts around 26% of dryer manufacturers, benefiting from strong process-industry linkages and supplier networks. Together, Maharashtra and Gujarat form the core manufacturing backbone for dryers and related separation equipment.

**Despite a strong domestic manufacturing base, the dryer segment remains highly import-dependent at the component level. Key inputs—including vacuum pumps, refrigeration compressors, nozzles, burner heads, and advanced PLC systems—are largely imported. A critical gap is the absence of domestic manufacturing capability for -40°C industrial compressors, which are essential for vacuum freeze dryers. As a result, high-end freeze-drying systems and their core components continue to be imported from Germany, the United States, and Italy. These imported parts account for a significant share of total CAPEX, making domestic dryers cost-competitive mainly at smaller capacities.**

For small- to mid-scale applications, domestic dryers like basic pilot spray dryers with capacities exceeding 500 kg/hour, typically priced between INR 3–15 lakh, remain competitive. Beyond these scales, manufacturers report challenges in maintaining performance consistency and process control, limiting their ability to compete with imported systems.

The primary structural challenges facing the dryer industry include:

- Component import dependence: Heavy reliance on imported compressors, vacuum systems, and automation components drives up the CAPEX.
- Reliability issues at scale: Indian freeze dryers face performance and reliability challenges in high-moisture food applications, often due to premature failures in vacuum pumps and compressors.
- Low capacity utilisation: Many mid-sized manufacturers operate at 50–60% utilisation, increasing per-unit costs.
- High automation costs: Full-system automation (PLC-controlled freeze dryers) significantly raises equipment prices, discouraging adoption by smaller OEMs.
- Fragmented market structure: Numerous small manufacturers and high levels of customisation limit economies of scale and sustained R&D investment.

> "Performance gaps in locally made components, dependence on imported refrigeration compressors, limited advanced process know-how, absence of dedicated R&D teams, and difficult access to industrial zones and government financing together highlight the structural challenges facing domestic manufacturing."
>
> **-Suresh Ravichandra, Co-founder, New Tech Engineering Solutions**

**3.3. Separators**

The Indian separator market is dominated by international brands that cater to companies in the food, biotechnology, and high-specification processing segments, supplying centrifuges, decanters, and filtration systems that meet stringent hygiene and performance standards. A limited number of Indian firms manufacture decanter centrifuges, filter presses, and basic solid–liquid separation equipment, primarily for dairy processing, sugar mills, and effluent treatment plants. Typically, these systems cater to bulk clarification and low-pressure applications.

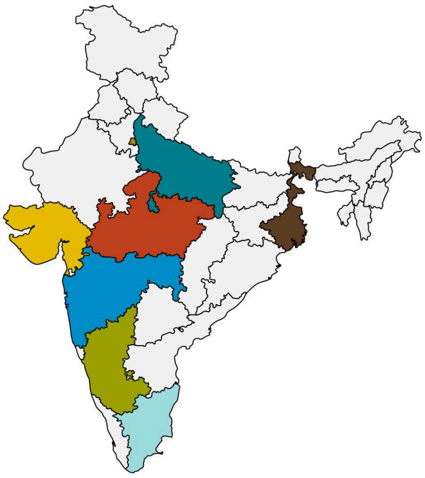
India currently has no established indigenous manufacturers of food-grade filtration membranes. While regional fabrication capabilities exist for frames, housings, and basic assemblies, precision components and hygienic systems are rarely produced domestically. **Critical subsystems—including membrane modules, high-speed centrifuge bowls, and hygienic pumps—are predominantly sourced from overseas suppliers. Advanced separation technologies such as ultrafiltration and microfiltration for protein concentrates and isolates are almost entirely import-dependent.** Based on the Ministry of Commerce data, in 2024-25, India imported approximately USD 1.6 billion worth of centrifuges and filtration equipment (4 digit HS 8421), while exports amounted to only a little over USD 1 billion.

Separator manufacturing in India is geographically dispersed, with clusters within dairy, sugar, and wastewater treatment ecosystems. These facilities tend to be small-scale, with limited capital investment and modest production volumes.

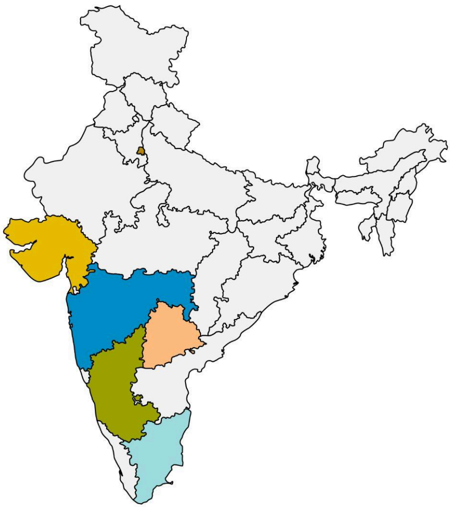
The primary structural challenges facing the separator industry include:

- Limited R&D and innovation: The industry relies heavily on reverse engineering rather than original design. Joint ventures and dedicated R&D facilities are rare.
- Precision and performance gaps: Domestic separators typically operate at lower rotor speeds (5,000–6,000 rpm) and achieve 60–70% yields, compared to significantly higher efficiencies in imported systems.
- Capital constraints: Domestic plants are typically small (capex approximately INR 2–3 crore), while large centrifuges and filtration systems can cost tens of lakhs of INR, putting them beyond the reach of many SMEs.
- Fragmented supplier base: Precision rotors, vacuum pumps, specialised valves, and even standard components such as variable frequency drives are largely imported. This dependence increases vulnerability to supply disruptions, and even small changes in vendor pricing or output can significantly impact margins.

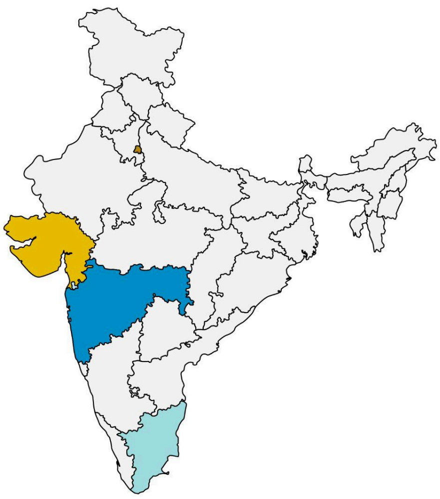
> “Reliance on imported automation and electronic parts adds cost and lead-time risk, affecting overall project efficiency and competitiveness.”
>
> **-Mr. Ramcharan Singh, Global Sales Manager - Food Equipment, Steer World**



| Extruders | | |
|---|---|---|
| **Region** | **Count** | **Percentage** |
| Delhi Belt | 14 | 29.79% |
| UP | 13 | 27.66% |
| Gujarat | 7 | 14.89% |
| Karnataka | 5 | 10.64% |
| Maharashtra | 3 | 6.38% |
| MP | 2 | 4.26% |
| Kolkata | 2 | 4.26% |
| Tamil Nadu | 1 | 2.13% |



| Dryers | | |
|---|---|---|
| **Region** | **Count** | **Percentage** |
| Maharashtra | 43 | 45.74% |
| Gujarat | 26 | 27.66% |
| Delhi Belt | 13 | 13.83% |
| Tamil Nadu | 3 | 3.19% |
| Telangana | 4 | 4.26% |
| Karnataka | 5 | 5.32% |



| Separators | | |
|---|---|---|
| **Region** | **Count** | **Percentage** |
| Gujarat | 22 | 34.92% |
| Maharashtra | 17 | 26.98% |
| Delhi Belt | 15 | 23.81% |
| Tamil Nadu | 7 | 11.11% |
| Goa | 2 | 3.17% |

*Figure 2. Distribution of manufacturers in India: extruders, dryers, and separators*

# 4. Global opportunity and demand outlook

## 4.1 Understanding the global demand for dryers, extruders, and separators

The domestic market for plant-based smart protein equipment is closely tied to India's large food-processing sector. Rising incomes and health trends are expanding plant-based product sales (projected to reach multi-billion-USD value in India by 2030). This implies a growing demand for processing lines for plant-based food processing. India exported ~USD 8 billion of processed foods in 2024-2025 (16 percent of total agriculture exports), up from 13.7% of exports in 2015, signalling increased value addition over commodity trading processing of indigenous crops[1]. This indicates a domestic market incentive for local equipment supply. Food processing as a sector has been prioritised by the government to modernise agricultural value chains in India. The sector is also a priority under the Make in India initiative, with the Ministry of Food Processing Industries implementing schemes to attract investment and develop infrastructure. Mega Food Parks with essential utilities and common processing facilities are being established in agriculturally rich areas, offering a plug-and-play model for entrepreneurs. Investment in these parks is recognised under the Harmonised List of Infrastructure Sub-sectors (HLIS), enabling easier access to infrastructure lending[2].

However, India's share of the processed foods export market remains small. In fact, even land-constrained economies in Asia like Thailand and Malaysia have over 50 percent of their agriculture exports as processed foods. Countries in Europe like the Netherlands are also close to 50 percent but with much higher absolute values of the exports[2]. Even globally, processed plant proteins are now a multibillion-USD industry worth nearly USD 3 billion, dominated by North America, Europe and China[3]. To compete in the exports market and increase the share of processed food in India's agriculture export basket, India's food processing sector needs to invest in efficient and advanced processing capabilities. With this agenda, the availability of food processing equipment in the domestic market becomes increasingly important if we are to capture a larger share of the world processed food market.

For the purposes of analysis of global trade dynamics in advanced food processing equipment, the analysis focuses on selecting a relevant set of HSN codes that could be classified under the three equipment categories of dryers, extruders and separators. The application of the three technologies is fairly wide and goes beyond protein processing, with their use case also in polymers, biopharma, and industrial processing in non-food areas.

*Table 1. Selected HSN Codes for analysing global trade*

| Equipment | Category | HSN Code |
|---|---|---|
| **Dryers** | Freeze dryers/Spray dryers/Industrial Lyophilisation | 841933 |
| | Industrial Agricultural Product Dryers | 841934 |
| | Non-domestic, non-electric dryers (nes) | 841939 |
| | Dryers for agricultural products | 841931 |
| **Extruders** | Bakery and pasta-making machinery | 843810 |
| | Industrial machinery nes for food and drink preparation | 843880 |
| | Industrial machine parts, food, drink preparation | 843890 |
| | Extruders for working rubber or plastic | 847720 |
| **Separators** | Machines to clean, sort, grade seed, grain, dry legume | 843710 |
| | Centrifuges nes | 842119 |
| | Machines to mill or work cereals or dried legumes nes | 843780 |
| | Parts of centrifuges, including centrifugal dryers | 842191 |
| | Filtering/purifying machinery for liquids nes | 842129 |
| | Parts for filter/purifying machines for liquid/gas | 842199 |
| | Parts grain, seed, dry legumes processing equipment | 843790 |

However, given the lack of exclusive HSN codes for some of this equipment meant specifically for use in industrial food processing applications, the analysis should still be indicative of the countries dominating the global markets. Additionally, since the foundation for drying, separating, and extrusion is based on  similar scientific principles across different applications, we believe the broad HSN codes are also a proxy measure of identifying the countries that overall dominate these technologies for industrial applications.

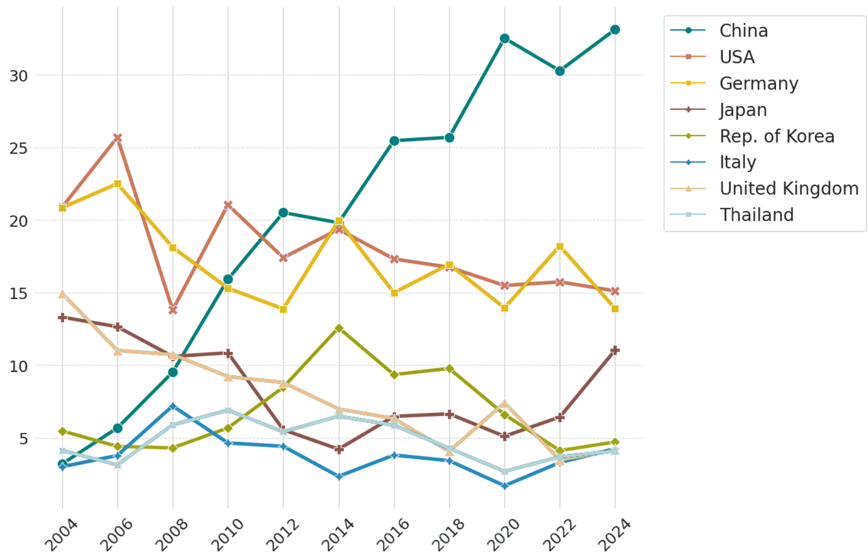


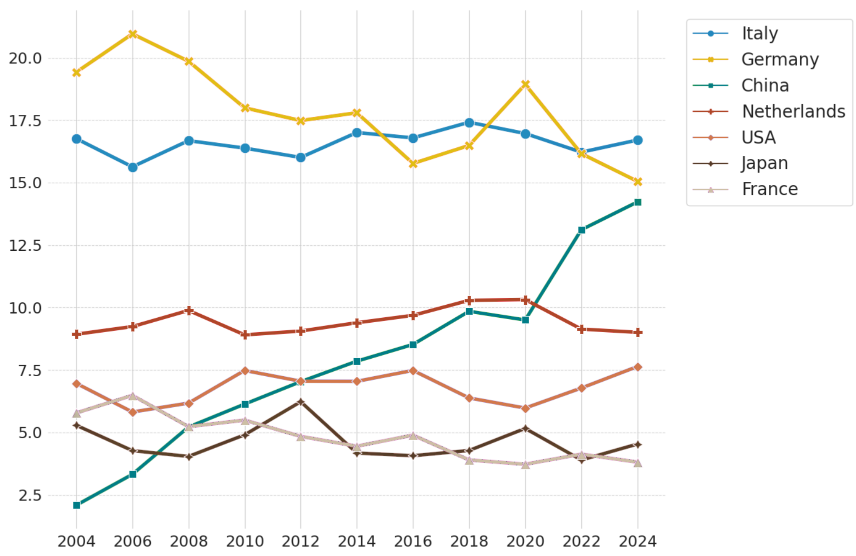

*Figure 3. Countries with largest market shares in India combined across categories*

Source: Author's calculation using UNCOMTRADE data

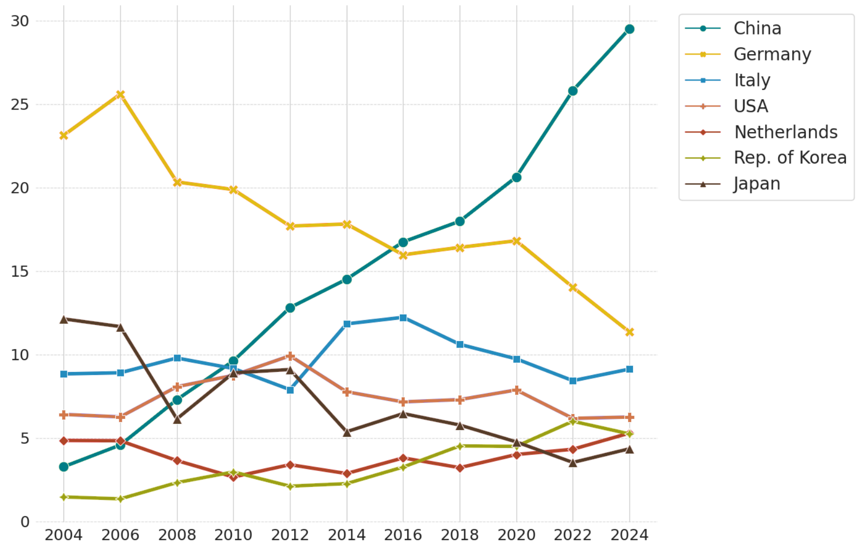
Despite the growing importance of advanced food processing, trade data highlights a gap: Indian equipment corresponding to selected HSN codes had exports of approximately USD 850 million compared to the imports of over USD 1.5 billion[4]. While India's export CAGR has been higher than the import CAGR, the difference in the absolute values is significant. In terms of India's trading partners, in 2004 India's major importing partners were the USA and Germany—both with a little over 20 percent market share—the UK, with about 15 percent and Japan, a little under that. However, their dominance significantly eroded in the next two decades, with the USA dropping to ~15.1 percent, Germany to ~13.9 percent and the UK to just ~4.2 percent. While still significant, they have collectively lost nearly a third of their market share to China. The lopsided trade figures for India and the overwhelming reliance on China notwithstanding, India continues to hold a strategic advantage of cost-effective engineering and economies of scale for certain products. Many stakeholders believe that resolving quality issues could enable Indian machines to compete internationally on price. From the perspective of trade flows, domestic manufacturing would reduce foreign exchange outflows and reduce vulnerability to currency swings.

### 4.2. Global market and countries dominating global trade

If we specifically focus on the categories of equipment that are being discussed in the report (using the selected HSN codes as proxy), the global market was worth over USD 54 billion in 2024. Historically, the global market for dryers has been consistently dominated by selected Western European countries like Germany, Italy, and the Netherlands, along with the United States. However, it's the change in market share where it's most revealing.




*(a)*

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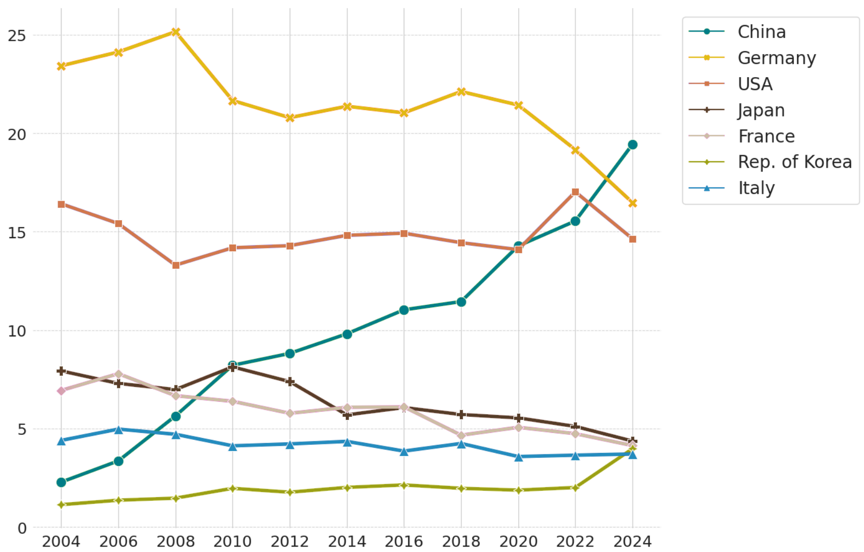


*(c)*

*Figure 4. Share of global export market of (a) extruders, (b) dryers, and (c) separators (in %)*

Source: Author's calculation using UNCOMTRADE data

For dryers, Germany was the leading exporting country in 2004, with a market share of a little under 25 percent for dryers and separators. It was also one of the leading exporting countries for extruders and had almost 20 percent of the market share. Italy was a close second with a ~17 percent market share for extruders. For all categories combined, Germany, with its reputation in global engineering, was a clear leader with a significant lead over the next major exporting country. For separators, it's worth noting that the HSN codes (842191, 842199, 843790), which pertain to equipment parts, account for over 50 percent of the global market. This indicates that the trade in key components and subsystems of separators is a major part of the global demand.

Overall, the market for this equipment until just two decades ago was led by a handful of Western European countries, along with the USA and Japan. Since then, over the last 20 years, Germany's consistent decline in the global market share across all three categories, with the sharpest decline for dryers (from ~23 percent in 2004 to ~11 percent in 2024), clearly overlaps with China's rise. It's worth noting, however, while data for the quantity of exports is not consistently available, the limited data does show that the number of items exported by European and North American countries was typically smaller than China, referring to a much higher per-unit value of their exports. However, the sheer increase in both the volume and value of exports for China over two decades and the commensurate stagnation or marginal increase in the market share of the other countries mean that China is not just dominating exports of equipment that require lower technological sophistication but is also gradually crowding out the share of historically dominant countries from the precision engineering applications.

### 4.3. The curious case of China's rise: What did they do differently?

China has been an anomaly when it comes to many indicators of industrial development. China made manufacturing a national mission immediately after the Reform and Opening-up in 1978. Industrial production and exports were placed at the centre of their growth and employment strategy rather than as a standalone sector. It rapidly moved labour from farms to factories and created Special Economic Zones, like Shenzhen, with tax breaks and infrastructure to attract industry. Sustaining this momentum, single-minded focus helped China reach about 28% of global manufacturing output by 2024, while India, which liberalised later, remained near 3%[5].

Even as China's dominance as a peripheral supplier of low-cost, low-complexity hardware grew, high-value, precision-dependent sectors continued to be the exclusive preserve of advanced industrial economies, with Germany, Italy, the Netherlands, and the United States forming an oligopoly of innovation and quality manufacturing in the late 90s and early 2000s. In the last two decades, however, China is gradually establishing itself as a dominant global exporter and a formidable competitor in the realm of precision engineering. Several major Western tech companies that established manufacturing facilities in China to improve efficiency and cut down costs are now looking at China as the place for innovation as well[6].

China, in fact, did not invent the innovation-led manufacturing growth model—in many ways it adopted a form of the 'Asian Tigers' path that led to the growth of countries like Singapore, Taiwan, and South Korea and, prior to that, Japan. Their growth model can be clearly split into the following phases:

**Phase 1:** In the early 1980s, when Deng Xiaoping opened up the Chinese economy to foreign investment, his economic development strategy sought principally to induce foreign multinationals to shift relatively low- and moderate-value production to China.

**Phase 2:** China's second step was to attempt to learn from foreign companies, in part by having them train Chinese executives, scientists, and engineers, as well as by forced technology transfer, including through joint ventures. This trend continues today: In 2015, China established 6000 new international joint ventures, amounting to USD 27.8 billion in FDI inflows, demanding a significantly high value and sophistication of technology. As the United States Trade

Representative's (USTR's) Office pointed out in its 2018 Special 301 report on China, the pressure on U.S. companies to form joint ventures and transfer technology "is particularly intense."

**Phase 3:** The next step included supporting Chinese companies' efforts to copy and incorporate foreign technology while building up domestic capabilities. One important marker for the transition from stage two to stage three was the publication of the "National Medium- and Long-term Program for Science and Technology Development (2006–2020)," which called on China to master 402 core technologies—everything from intelligent automobiles to integrated circuits and high-performance computers. China moved to a "China Inc." development model of indigenous innovation, focusing on helping Chinese firms, especially those in advanced, innovation-based industries, often at the expense of foreign firms.

Phase 4: The fourth and final step is enabling Chinese firms to become independent innovators following the examples of Japan, Singapore, South Korea, and Taiwan. China is attempting to do this through an array of plans and policies: "13th Five-Year Plan for Science and Technology", "13th Five-Year Plan for National Informatisation", "The National Cybersecurity Strategy", and "Made in China 2025 Strategy", and most recently Xi Jinping's call at the 20th Party Congress for "invigorating China through science and education... for the strategy of innovation-driven development".

*-From "China Is Rapidly Becoming a Leading Innovator in Advanced Industries", ITIF (2024)*[7]

China's manufacturing ecosystem encourages risk-taking through strong state-backed financial support. When exporters face temporary shocks, state-owned banks and local governments often intervene by restructuring loans or extending support to protect employment and industrial capacity, reducing the likelihood of firm failure. Access to patient, low-cost capital enables Chinese firms to invest in large capacities and new export markets despite uncertain returns, thereby supporting rapid scale-up.

"Imported dryers, particularly from China, often enter the market with strong price advantages supported by domestic subsidies in the country of origin. The absence of equivalent support mechanisms in India reduces competitiveness of local OEMs. A structured subsidy or incentive scheme for Indian dryer manufacturers is required to improve affordability and scale."

**-Mr. Syed Awais, Director, Universal Process Engineers**

Note: For a more detailed understanding of China's growth model, along with a comparison of how it approaches national development through tech-based manufacturing and the strengths (as well as some challenges) of the China model, we recommend going through the full report by ITIF.

**4.4 Priority markets and positioning for India as an export challenge**

The major importers of the equipment are spread between the Western economies and Asian countries. The recently concluded or about to be concluded FTAs with developed economies like the EU, the UK, and the USA and others theoretically open up the opportunity for Indian food equipment manufacturers to the world's largest markets. However, these markets are highly competitive and India will continue to face non-tariff barriers on quality standards and other technical barriers to trade (TBT). Most Indian machinery exporters struggle to meet the norms of these markets, while many Indian standard-setting bodies continue to not be recognised. In several previous FTAs with countries in ASEAN, Japan, and South Korea, despite Indian exports rising in overall value, it was the imports of high-value, capital-intensive goods that grew the fastest[8]. Even for the broader 'engineering goods' sector, of which extruders, dryers, and separators are a subset, India is not competitive in products with a large global market, with export dominance being limited to resource-intensive, low value-add goods that have a small market size[9].

While African countries at this point hold a smaller share of the global market, they are growing and emerging as an important market, as their agrifood sectors and overall economy industrialise. Given India is taking a proactive approach when it comes to FTAs with other major economies, by adopting the right policy and ecosystem support, it can significantly improve the value of its exports of engineering products with countries that are leading the market. At the same time, emerging opportunities with developing countries present a lucrative advantage for India's MSMEs to cater to with their favourable price-performance ratio and lower demands for precision compared to the more mature and competitive markets.

To understand the promising export markets for India, market size data from 2004 to 2024 for the 60 largest countries were analysed. The market size was calculated as the average import value for countries between 2016 and 2024 to account for volatility in single-year measures. Given there are year-to-year variations, with recent values being significantly larger than earlier values, as well as the absolute size of the markets being vastly different across countries, a log-linear regression model was used to calculate the growth rates and plot against the log-linearly transformed averaged market size. Using the median market size and the median growth rate as thresholds, markets have been categorised based on growth and volume into the following:

- Priority targets (High Volume, High Growth)
- Future potential (Medium Volume, High Growth)
- Mature markets (High Value, Low Growth)
- Watch list (Low volume, Low Growth)

For the purpose of this report, the first two categories have been explored in greater detail. The latter two categories, while important, are primarily countries where the market is generally viable for precision and highly specialised products that need to meet stringent standards (mature markets) or are still too small and niche (watch list).

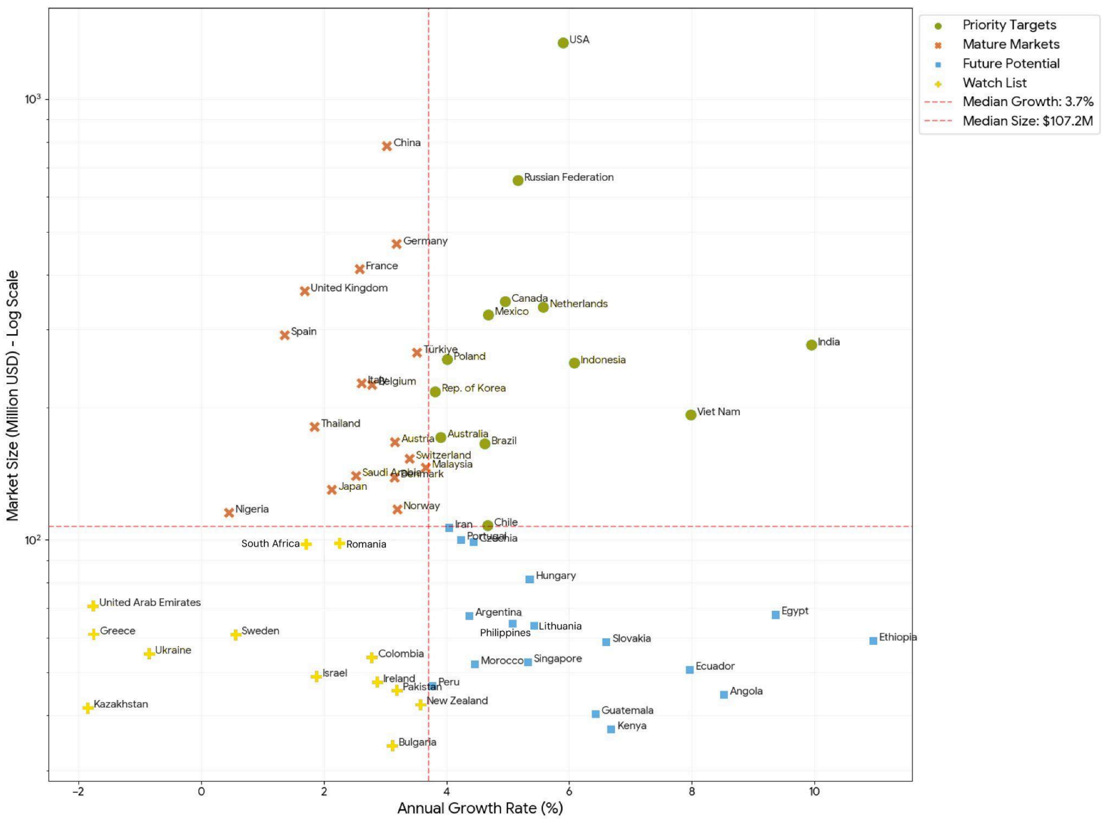


*Figure 5. Largest importers of extruders by value and growth rate*

Source: Author's calculation using UNCOMTRADE data

**Priority targets:** Russia, Vietnam, Indonesia, Mexico, Brazil, Saudi Arabia, and Malaysia

Russia (USD 653M, 5.2% growth) is a massive opportunity (Fig. 5). With Western sanctions limiting European supplies, there is a vacuum that Indian manufacturers are well-positioned to fill given existing bilateral ties. Southeast Asian countries like Vietnam and Indonesia are rapidly industrialising and already have markets that are growing—at eight and six percent, respectivel–with imports of  over USD 250 million, according to the latest available import data. While Saudi Arabia and Malaysia are classified as mature markets given their relatively large markets and slow growth, they're close to the threshold and are rapidly industrialising economies with high potential markets. South American nations such as Mexico and Brazil are also fast-growing markets for extruders—valued at over USD  450 million and USD 250 million, respectively—based on the latest data.

**Future potential:** Africa (Ethiopia, Egypt, Kenya, and Angola), Eastern Europe (Slovakia, Hungary, and Czechia), Latin America (Ecuador, Chile, and Argentina)

The emerging economies in Africa, Eastern Europe, and Latin America are by far the fastest-growing markets. Countries in Africa in particular are growing ~10 percent with growth being especially rapid in recent years. Eastern European countries are also extensively investing in industrialising their economies, as is reflected in their heavy imports. While Latin American countries have comparatively low growth, the markets are substantial,  valued at approximately USD 100 million.

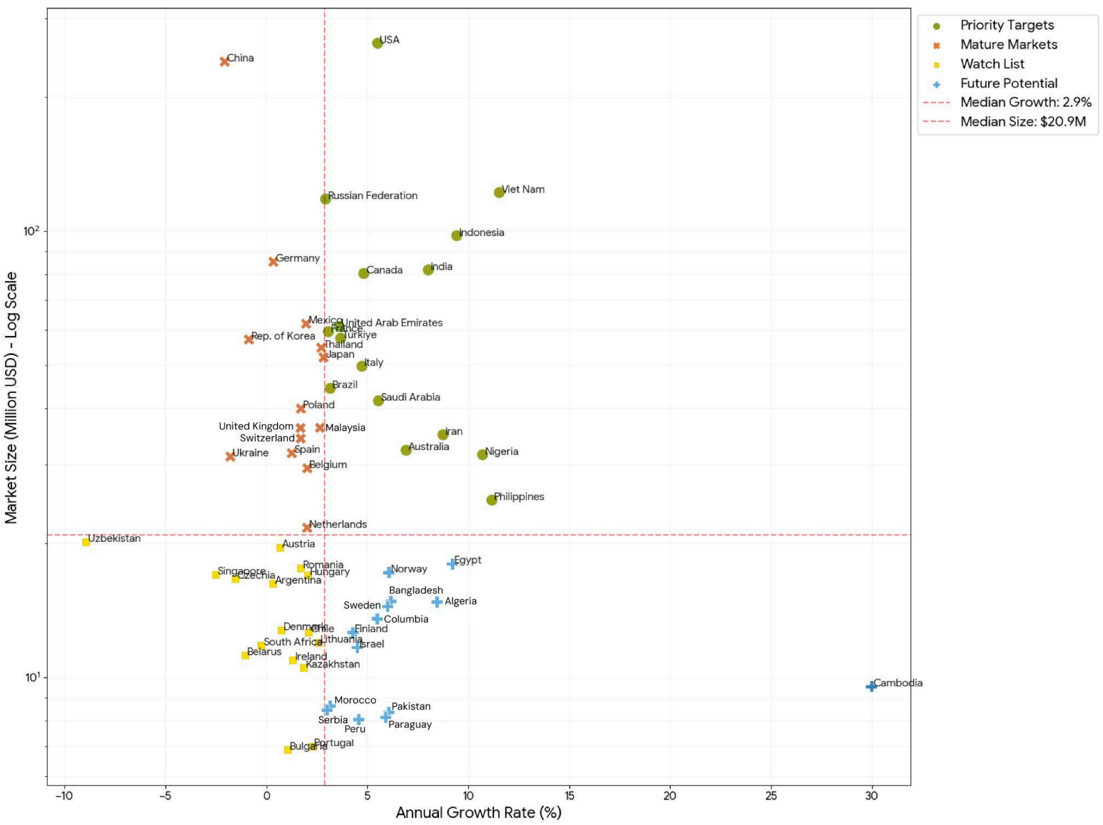


*Figure 6. Largest importers of dryers by value and growth rate*

Source: Author's calculation using UNCOMTRADE data

**Priority targets:** Asia (Vietnam, Thailand, Indonesia, Philippines, Russia, Saudi Arabia, UAE), Africa (Nigeria)

The dryers market is smaller than the extruder and separators market.  Countries like Vietnam, Indonesia, and Thailand are growing at ~ ten percent (Fig. 6) and  have relatively large markets of close to or approximately USD 100 million. Given the overall lower size of the global market, Nigeria (approximately USD 32 million), in particular, features in the priority markets for dryers, registering double-digit growth over ten percent.

Russia again emerges as a high-value market given geopolitical conditions. While growth rates are below ~three percent, it has one of the largest markets after the USA and China.

**Future potential:** Asia (Vietnam, Bangladesh, and Cambodia), Africa (Algeria, Egypt, and Morocco).

The markets identified here are small and nascent. However, Indian companies will be able to establish themselves without stiff competition if they act early.

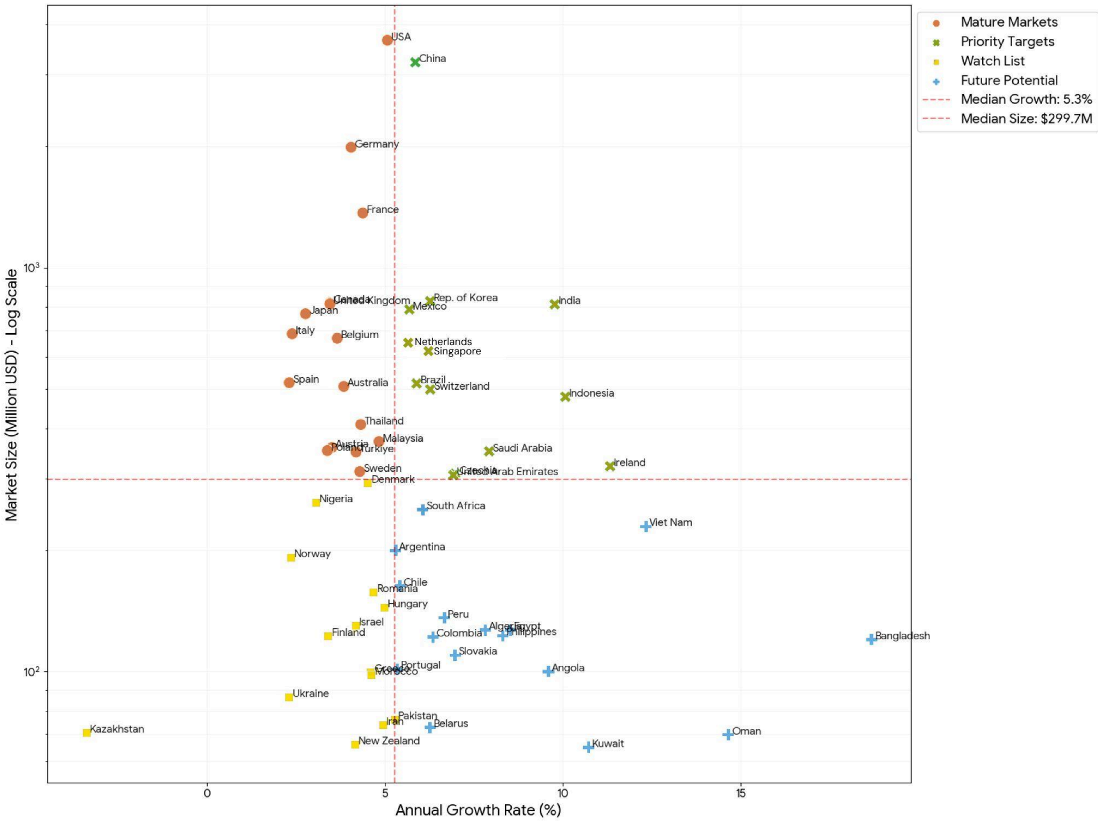


*Figure 7. Largest importers of separators by value and growth rate*
Source: Author's calculation using UNCOMTRADE data

**Priority targets:** Asia (Indonesia, Saudi Arabia, UAE), Latin America (Mexico, Brazil)

The global separators market is substantially larger than extruders. Overall, it's a faster-growing and higher-volume space. The Indonesian market is growing at double-digit rates and is already at over USD 700 million in 2024. The Middle Eastern nations like Saudi Arabia and the UAE are also emerging as major markets, with both being worth approximately USD 400 million. Mexico and Brazil continue to anchor the demand for capital goods in South America with markets worth over USD one billion and approximately USD 700 million, respectively (Fig. 7).

**Future potential:** Asia (Vietnam, the Philippines, Bangladesh, Kuwait, and Oman), Africa (Angola, Algeria, Egypt, South Africa, and Nigeria).

The Middle East and Africa continue to drive the growth rates for separators as well. Countries like Nigeria and Egypt are approximately USD 150 million, whereas South Africa has crossed USD 400 million. The markets like Oman and Kuwait in the Middle East are comparatively smaller, ranging from approximately USD 50-70 million but are growing over 10 percent. India's neighbour Bangladesh is, in fact, the fastest-growing market, with the current market of over USD 100 million.

India's ambition to become a hub hinges on competing with countries on cost and performance, specifically the price-performance ratio. Interestingly, India is also consistently emerging as a major importer of this equipment with a fairly high growth rate. And, while India is exporting equipment, the share of the global market that the country commands is very small. Between 2004 and 2024, while India's value of exports grew, India's share of the total global market continued to remain less than three percent for dryers, nearabout four percent for extruders, and has never crossed 1.5 percent for separators as per the latest export data.

At this time, India's MSME sector will benefit from gradual expansion, starting with the markets in the developing countries of the Middle East and Africa, as well as special cases like Russia. After building a sustainable cash flow and capacity for R&D, India should eventually aim to export to mature markets where there is demand for greater technological sophistication. All of these markets, of course, should be looked at in addition to catering to the burgeoning domestic market, which currently remains dependent on imports. Not just finished machines, there are major opportunities in the spare parts trade–with spare part HSN codes (included under Separators for our analysis) accounting for more than 50 percent of the global trade of separator equipment.

## 5. Technical benchmarking and innovation assessment

Technical specifications and design capabilities of processing equipment play a central role in manufacturing plant proteins and plant-based meat products with desirable functionality, texture, and structural properties. This section presents an appraisal of the technical specifications of extruders, dryers, and separators in India, comparing domestic capabilities against international standards. In addition, the patent and innovation landscape of extruders, separators and dryers is evaluated to identify opportunities for technological advancement.

### 5.1. Extruders

In extrusion-based processing or texturisation of plant proteins, parameters such as specific torque, screw speed, and L/D ratio are key indicators of process capability. High specific torque is essential for processing viscous, high-moisture plant protein formulations and generating the shear required for protein unfolding and fibrous alignment (anisotropicity) that are critical for creating meat-like textures. Higher screw speeds support uniform mixing, stable flow, and commercially viable throughput under continuous operation. The L/D ratio influences residence time and the number of functional zones (mixing, kneading, cooking, venting, and cooling), which are important for controlling shear, thermal history, and structure development, particularly for high-moisture processing and fibrous texture formation. Longer L/D ratios and precision gearing therefore ensure sufficient residence time and mechanical stability. Limitations in these parameters directly constrain the ability to produce consistent, anisotropic, meat-like textures at an industrial scale.

Currently, several critical gaps limit India's self-reliance in manufacturing high-performance extrusion systems. Only a few domestic manufacturers have built pilot-scale facilities for prototyping high-moisture extruders. Economies of scale remain limited, and many workshops produce machines only up to a certain tonnage. Building larger-capacity models requires investment in large lathe machines, precision machining, and advanced quality control systems. While Indian manufacturers are competitive in basic and mid-scale equipment, they lag in high-performance, precision, and hygienic systems required for smart protein processing. At the same time, several Indian OEMs have begun implementing cost-efficient engineering solutions at pilot and early-commercial scales. Modular extruder lines are being designed for customisation, with some domestic systems allowing screw elements to be swapped for different recipes. Pre-assembled modules such as feed, extruder, and cutter units can be partly assembled locally and customised at lower costs. Indian alloys (e.g., bimetallic cladding for barrels) are increasingly being used to reduce reliance on expensive imports. Powder-coated steel frames and locally cast components are standardised, but critical precision parts are still being imported. Upgrades to HMIs and remote monitoring via affordable IoT sensors and open-source PLCs are underway, improving usability without major cost escalation. Test projects using Indian-made PLC modules and locally supplied sensors indicate early movement toward smarter, digitally enabled extrusion systems.

### 5.2. Dryers

Drying is yet another key technology for India's smart protein processing ecosystem. Similar to extruders, Indian manufacturers are strong in small- and medium-scale dryers but have limited capability for large industrial systems. Advanced configurations such as two-stage spray plus fluidised-bed dryers, which are common in global plants, are capable of reducing energy consumption by ~11% compared to a single-stage operation. However, most Indian systems are not optimised for such multi-stage integration.

Freeze dryers produced in India are largely restricted to lab and pilot scales, with no domestic offerings comparable to imported large-scale industrial lyophilisers. Domestic freeze dryers typically have longer cycle times and higher energy consumption and rely on limited in-house design expertise. Design parameters including mode of operation (batch *vs.* continuous), scalability, and system integration are critical for reducing cycle time and specific energy consumption. Current gaps limit the suitability of Indian freeze dryers for large-scale, high-throughput applications.

Fluidised-bed dryers used in India are generally smaller-scale and designed for simple batch operations. Flow distributors may be rudimentary, with limited control over temperature zones. In contrast, global systems feature uniform perforated plates, multi-zonal airflow, and tight process control through mass-flow controllers and humidity sensors. International designs often integrate Process Analytical Technology (PAT) probes and enable gentle, uniform fluidisation. Many Indian models rely on fixed-speed blowers and manual dampers, which can lead to uneven drying or agglomeration. Importantly, combining fluidised-bed dryers with spray dryers in multi-stage configurations yields efficiency gains that domestic manufacturers rarely exploit.

Global flash dryers (high-velocity), used for rapid drying of slurries or particulates, incorporate advanced flame monitoring, multi-zone heating, and full automation to ensure consistency and safety are largely absent in local models. The capacity for domestic manufacturing, particularly for high-speed airjets, fuel-gas burners, and precise control systems, is limited. As a result, Indian flash dryers tend to be basic, with fixed combustion airflows and limited recirculation, relying heavily on operator skill.

### 5.3. Separators and membrane filtration systems

Similar capability constraints exist in separation and filtration technologies. Only a few Indian companies have built large-scale separator manufacturing facilities. While some small-scale manufacturers serve the dairy or agro-processing sectors, producing a 1000+ L/h decanter or a

5m³/h membrane system demands specialised tooling and ultra-precision engineering capabilities. Subcontracting critical components such as bowls and seals further complicates mass production.

Indian firms manufacture basic solid–liquid separators, but high-performance systems remain largely imported. Imported disc-stack centrifuges typically achieve 7,000–10,000g with automated discharge, whereas domestic designs generally operate at approximately 2,000–3,000g and are often batch or semi-automatic.

India also lacks a domestic industry capable of manufacturing food-grade ultrafiltration membranes. Most Indian filtration units are adapted from water-treatment designs, with larger pore sizes and lower selectivity. Consequently, even membrane skids built in India must import the membrane modules. Without an indigenous membrane manufacturing base, performance remains suboptimal, with yield losses and faster fouling.

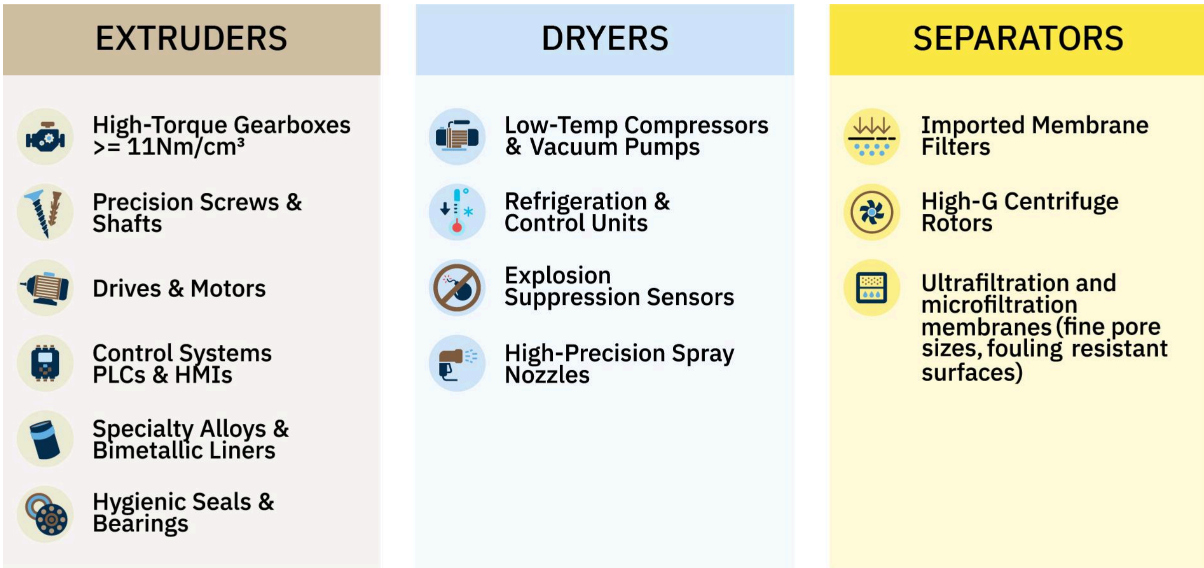


*Figure 8. Import-dependent core components of extruders, dryers, and separators*

> “Several critical components are still imported. For example, membrane fabric is often sourced from Japan due to its superior quality and the lack of comparable domestic alternatives. This dependence on imports affects core equipment functionality, highlighting the need for a focused national R&D programme to develop high-quality membrane-fabric technology in India.”
>
> **-Mr. Shreyas Vagadi, Director, Osmotech Membranes Pvt. Ltd**

Air classification is a critical dry fractionation approach for producing protein-rich flours and concentrates from plant-based sources. This technology enables efficient separation of fine protein-rich particles from coarser starch fractions through controlled airflow and centrifugal forces. When integrated with precision milling, this dry, water-free approach offers a sustainable alternative to wet fractionation and reduces downstream dependency on membrane filtration and effluent treatment. Advanced classifier systems usually work in closed-loop pneumatic circuits with blowers, filters, and dust control mechanisms to ensure product purity and operational safety.

Industry stakeholders emphasise the importance of hygienic design (e.g., SS 304 construction), easy cleanability for batch operations, and effective dust collection systems to minimise product loss and downtime. Indigenous manufacturers are capable of supplying air classifiers for food and protein applications, including R&D and commercial-scale protein shifting units, with strong customisation and service support. Performance parameters such as cut size precision, energy efficiency, and integration with upstream milling significantly influence protein yield and functional quality.

Discussions also highlighted that ultra-fine milling equipment required to achieve the particle size reduction necessary for effective starch protein separation prior to air classification is not manufactured domestically in India. Such systems typically demand micron-level grinding precision (often <20–30 μm), classifier-integrated impact or jet milling technologies, and wear-resistant, food-grade construction. At present, high-precision jet mills, pin mills with dynamic classifiers, and other ultra-fine grinding systems suitable for protein fractionation are largely imported. The absence of indigenous ultra-fine milling capabilities limits the efficiency of dry fractionation processes and constrains the overall performance of downstream air classification systems.

### 5.4. Technological capabilities: Domestic *vs.* imported

This section represents a comparative appraisal of the technical specifications of extruders, dryers, and separators between India and international standards across key dimensions such as scale and performance; design, efficiency, and hygiene; and controls, functionality, and safety (Table 2).

*Table 2. Comparison of the technical specifications of Indian vs. imported equipment*

| Equipment | Design & efficiency gaps | Hygiene gaps | Controls, functionality & safety gaps |
|---|---|---|---|
| **Extruders (twin-screw extruders for high-moisture extrusion)** | Lower specific torque and screw speeds* (~60–1200 RPM *vs.* the global benchmark of 1200–1800 RPM; >1000 RPM for food applications) of Indian extruders compared to their imported counterparts,[10,11,12,13] limit throughput and capability to process viscous/high-moisture feeds (Fig. 5).<br><br>Domestic extruders typically have lower L/D# ratios and less precise gearing, which reduces flexibility and efficiency compared to imported systems with modular screw architectures.<br><br>Gear precision is low in domestic design, whereas imported extruders use hardened gears and precise alignments to maintain torque. Indian gearboxes have greater backlash.<br><br>Many Indian extruder models were adapted from snack or animal-feed machines. Their frames may have exposed bearings and weld seams where products can lodge. | Only a few domestic extruders feature fully enclosed, electropolished barrels; most lack CIP-ready hygienic design, increasing microbial risk and cleaning costs. Whereas imported extruders are designed to be CIP-ready with minimal maintenance.<br><br>While domestic extruders have semi-welded, external bearings, which can lead to higher contamination risk and longer downtime, imported extruders feature fully welded SS, CIP spray balls.<br><br>No widely adopted domestic sanitary certification (e.g., 3-A, CE, EHEDG equivalent); the absence of recognised approvals limits acceptance in regulated and export markets. | Advanced features critical for smart-protein applications, such as precise thermal zoning, vacuum venting, in-line cooling, and automated recipe control, are largely missing in Indian designs.<br><br>Intermeshing co-rotating screws, complex screw mixing sections, and precisely controlled cooling dies and thermal gradients required to induce anisotropic fibrous structures in high-moisture protein matrices are rarely native to Indian units.<br><br>Most extruders in India have basic PLC interfaces and 1–2 control axes. High-end features such as recipe control, variable-frequency drives for torque control, and sensor arrays (for melt pressure and temperature profiles) are often add-ons or missing. Without these, processors cannot replicate the fine control needed for whole-cut plant-based meat products. Imported extruders have multi-axis PLC/SCADA and feedback sensors. |
| **Dryers (spray, fluidised-bed and freeze dryers)** | Domestic spray dryers are typically single-stage (~1200 kcal/kg of water evaporated) with simple cyclone/bag filters and | Domestic dryers often require manual cleaning and basic filtration, whereas leading international OEMs have | Domestic dryers typically have basic safety provisions but often lack explosion suppression, fire detection, and HEPA-grade air filtration. |

limited integration of advanced energy-saving features (e.g., heat recovery systems). Imported spray dryers increasingly adopt two-stage designs (spray + fluid-bed drying) and multi-stage drying, along with heat recovery, fine process control and multi-stage heat exchangers. These integrated spray dryers improve overall energy efficiency by ~10–11% versus conventional domestic configurations.

Domestic spray dryers often have only hand-operated valves and manual inlet/outlet thermocouples, while international units deploy fully digital PID control loops, real-time sensors, droplet scanners and online analysers.[14,15,16]

Domestic freeze dryers are largely configured for small-to-medium batch sizes: ~10–200 L batches (up to ~10 m² of shelf area)[17]; limited shelf area and condenser capacity restrict scalability. Whereas, global systems span 6–41 m² of shelves with condensers of 100–800 kg/24 h capacity.[18]

Local freeze dryer systems typically achieve −40 °C to −55 °C shelf temperatures with ±1 °C control accuracy; global benchmarks are moving toward deeper freezing built CIP/SIP cleaning, HEPA filtration, explosion protection, smooth hygienic interiors, 24/7 automated monitoring and quick-access designs to reduce contamination risk and downtime.

Leading imported spray dryers include smooth-welded interiors and automatic access doors, whereas many Indian machines have exposed ductwork and require manual cleaning.

Globally benchmarked dryers integrate fire and explosion monitoring, sterile air handling, and multi-layered safety interlocks.

Control systems in many Indian dryers are relatively simple, relying on hand-operated valves, basic thermostats, or standalone PLCs.

Advanced explosion protection systems and fully integrated PLC/HMI controls often depend on imported technologies or components.

Indian dryers commonly use SS304/SS316 construction; CIP may be available but is not always fully integrated with advanced safety and control architectures.

Safety and control systems differ sharply: global OEMs incorporate explosion suppression and process automation platforms for real-time optimisation, while domestic counterparts typically use basic PLC/SCADA or manual control with minimal automation.

| | | | |
|---|---|---|---|
| | (~–80°C) with PID controllers, faster freezing, and higher condenser loads.<br><br>Indian machines offer batch freeze drying with PLC control, basic vacuum/compression (~25 kWh/cycle), ±1 °C shelf accuracy and optional CIP.[19] Global systems support a much larger scale with tens of m² of shelves, hundreds of kg/day capacity,[20] faster freeze rates and remote vacuum systems, advanced insulation, heat recovery, and remote condition monitoring.<br><br>Domestic units use standard SS 304 chambers and oil-based compressors, whereas global lyophilizers incorporate high-efficiency vacuum pumps and refrigerant chillers that can attain shelf temperatures up to –80 °C.<br><br>Performance gaps in freezing depth and condenser capacity increase cycle time and specific energy consumption, limiting suitability for large-scale, high-throughput applications. | | |
| **Separators (Centrifuges & filtration)** | Indian decanters and disc centrifuges achieve only a few thousand (×g) of Max G-force (~600×g - basket to 2–3,000×g - decanter); whereas, the global best practice is to deliver 7,000–10,000×g | Domestic centrifuges often have internal weld grooves and rubber seals not rated for extended dairy/food use. Imported machines come with polished internals and automatic | In the Indian scenario, there are no indigenous membranes and imported UF/MF membranes are used, whereas global best practice involves in-house membrane technology (e.g., membranes developed by companies such |

| | | | |
|---|---|---|---|
| | continuously. Consequently, Indian separators struggle to consistently clarify fine protein slurries at industrial throughput.<br><br>India lacks domestic production of extremely high-strength alloys and ultra-fine balancing facilities, required for safe operation at >3,000 rpm. | CIP systems.<br><br>While Indian machines use SS304 or carbon steel components, imported machines commonly use polished SS316, SS316L, EHEDG-grade steel, enclosed hygienic geometries, and CIP-validated cleaning loops, while many Indian designs have external weld seams and require manual disassembly for cleaning, increasing contamination risk and downtime. | as Pall and Merck).<br><br>While local firms may supply filter housings, domestic designs may use lower-cost elastomers that are not consistently qualified for prolonged contact with protein streams, raising concerns around food-grade compliance, durability, and process reliability.[21] |

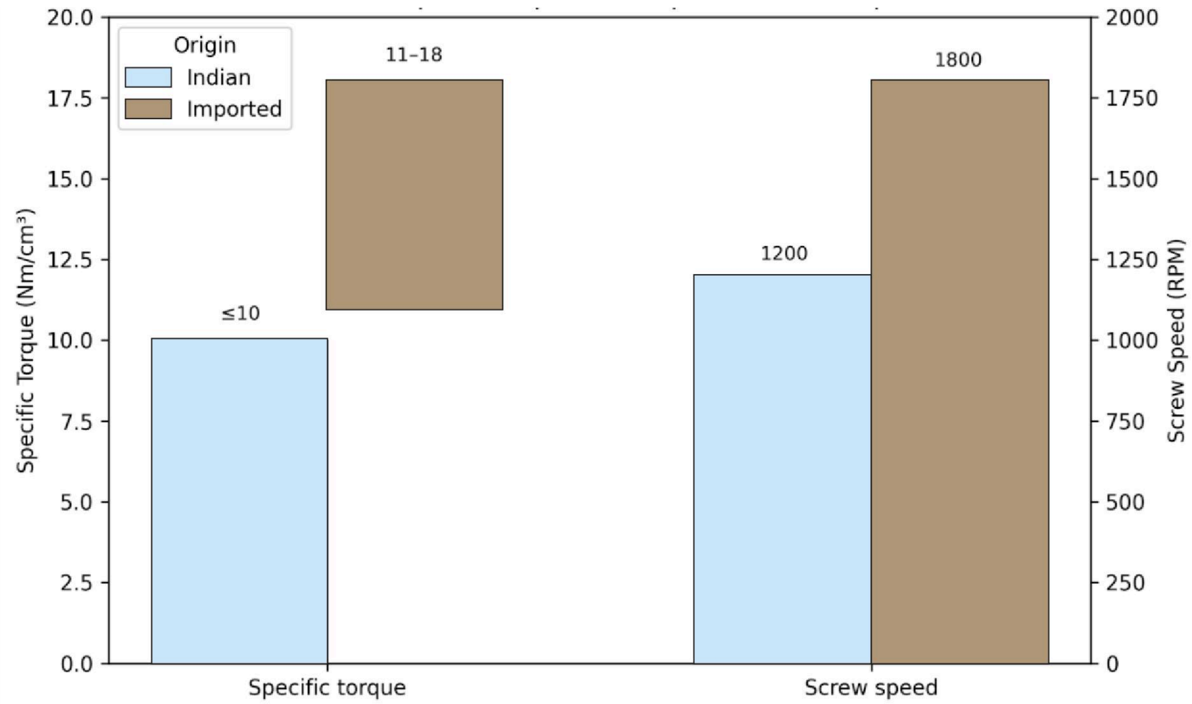


*Figure 9. Indian vs. imported extruders: Specific torque and screw speed*

**5.5. Patent and innovation landscape**

Patent filing patterns provide a useful indication of the direction of technology development and innovation priorities. Extrusion, separation, and drying are unit operations that fall under the following well-established Cooperative Patent Classification (CPC) families:

- Dryers/drying solid materials: CPC F26B (drying of solid materials/objects by removing liquid)[22, 23]
- Food-processing machinery: CPC A23N (machines/apparatus for treating harvested produce)[24, 25]
- Separations used in food processing/smart protein sectors (centrifugation, filtration/membranes) are often filed under mechanical/chemical separation classes (e.g., centrifuges, filtration/membranes), spanning multiple CPC groups

As per our analysis using Google's patent search engine, the Indian patent landscape for extruders, dryers, and separators is dominated by utility patents*, with very limited or no design patents#. These utility patents focus on extruder components and elements and functional and process innovations such as improved mixing, energy efficiency, drying uniformity, and enhanced separation or filtration performance. However, when it comes to design patents for any of these equipment types, India lags behind other countries like Japan, Germany, the United States (US), and Switzerland (Fig. 10), reflecting strong protection of the visual, structural, and ergonomic design of processing machinery in those countries. Although the US shows no design patents for food centrifuges, its overall emphasis on industrial design remains far ahead of India. China demonstrates an even more aggressive design-patent strategy, specifically for food-related centrifuges. With limited pathways from prototypes to validated products, India is well behind the US and China in safeguarding industrial design—limiting its competitiveness in global equipment innovation. The data shows that the innovation capacity in this equipment segment is uneven. A small number of firms invest in advanced design, prototyping, and performance improvements, but many manufacturers rely on adaptation of existing designs or reverse engineering. Stakeholders described this choice as a rational response to market conditions. When demand is uncertain and testing infrastructure is limited, firms prioritise delivery and fabrication over long research cycles.

The patent landscape analysis indicates that India is more often a 'market/jurisdiction of interest' where global equipment makers also seek protection, rather than the primary origin of the biggest equipment patent portfolios. For instance, global drying/atomisation equipment players file multi-country families that include India among protection jurisdictions.[26]

> "Weak support for patenting and commercialisation means many homegrown innovations fail to reach the market, highlighting the need for dedicated IP funding and commercialisation mechanisms."
>
> **-Dr. Prabhat Kumar Nema, Professor (Department of Food Engineering), NIFTEM-K**

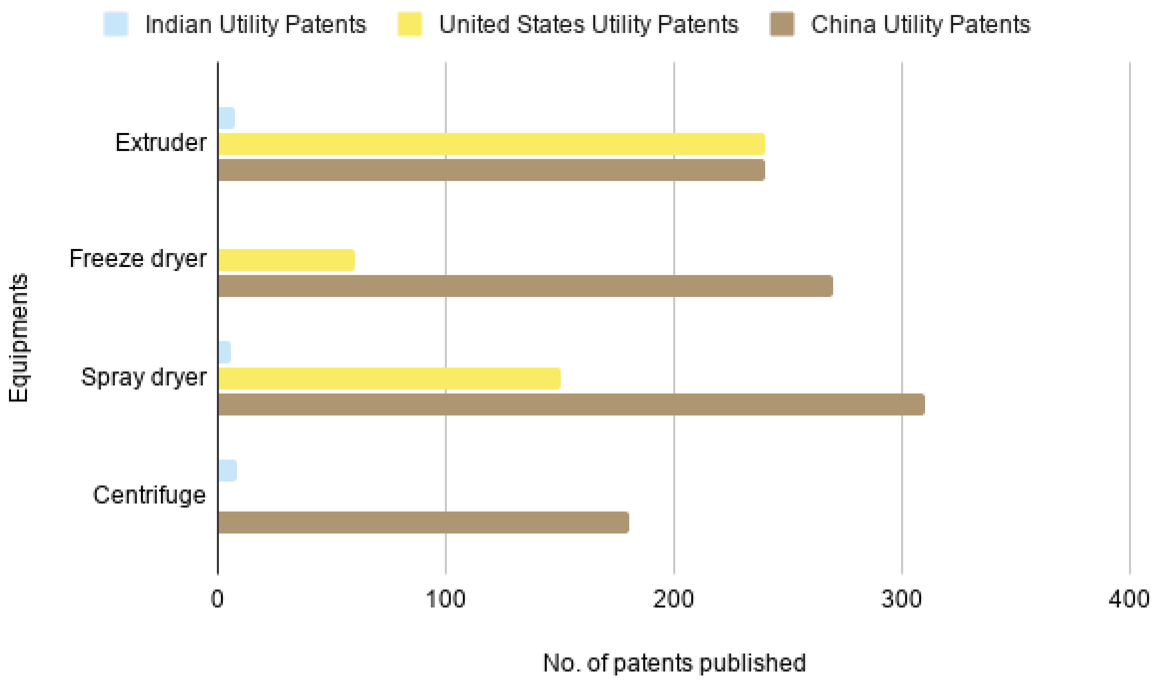


*Figure 10. Utility patent landscape as of 2025 (Figures in numbers)*

Innovation is not only about creating new machines. It is also about solving specific performance problems at a lower cost. For India to compete globally, it needs a steady pipeline of improvements in areas that buyers value most. These include energy efficiency, hygienic design, reliability under continuous operation, automation and monitoring, and component durability.

The research identified several priority areas where domestic innovation would have high leverage:

- Extrusion design, especially screw elements and cooling die performance for high-moisture products.
- Drying system integration, including energy recovery, safety systems, and control improvements.
- Separation and filtration performance, especially membrane development and hygienic high-speed separation.
- Materials and wear parts, including food contact seals and surface treatments that reduce fouling and improve cleanability.
- Digital controls and monitoring, including diagnostics, that improve uptime and reduce operator variability.

## 6. Structural and policy environment

India recognises food processing and capital goods as priority sectors. The National Capital Goods Policy (2016) explicitly targeted 'food processing machinery' for *Make in India* capacity-building. Under this policy's Phase I, the 'Enhancement of Competitiveness in the Indian Capital Goods Sector (ECIGCS)' scheme supported 33 projects with a budgetary allocation of INR 583.312 Cr., while Phase II (2022–27) allocated INR 1,207 crore to promote Industry 4.0 and indigenisation in capital goods[27][28]. India also passed the much-publicised PLI scheme for capital goods, although it was intended primarily for the Advanced Automotive Technology (AAT) Products, with a capital outlay of INR 25,938 crore for a period of 5 years (FY2022-23 to FY2026-27)[29].

The PLI Scheme for Food Processing (PLISFPI) provides INR 10,900 crore to boost manufacturing of processed foods (ready-to-eat, marine products, etc.).[30] Though PLIs mainly target processed foods rather than machinery, they indirectly drive equipment demand. There is a clear opportunity to identify such convergences and interlinkages to ensure that schemes don't work in isolation. For instance, the support for the food processing sector could have created an even larger impact if there were schemes that also supported the manufacturing of high-quality food processing equipment in India. Planned convergence can create multiplier effects by enhancing the impact of the schemes in tandem. Despite this, no major scheme specifically incentivises the production of food processing equipment. Even newly announced schemes like the Research Development and Innovation (RDI) fund[31] as well as the National Manufacturing Mission[32] do not identify advancement of food processing machinery as a priority area. The limited focus on capital goods for the food processing sector has meant that in the period of 2014-15 to 2024-25, food processing machinery is the only sub-sector whose production value has declined—from INR 20,000 Cr to approximately INR 15,000 Cr[33].

### 6.1. Current environment for advanced food processing equipment manufacturing

Industry members indicate that the lack of a programme focused specifically on advanced food-grade capital goods leads to treating manufacturers of extruders, dryers, and separators like any other engineering MSME, without recognising the higher precision, compliance, and validation requirements of food-processing equipment. In this context, states that provide direct capital and interest subsidies are structurally better aligned with equipment OEM needs than models that rely primarily on SGST reimbursements, which are realised only after revenue generation. Although industrial parks and cluster schemes exist, none of them strategically focus on food-grade machinery manufacturing, and there are no dedicated hubs with common validation labs or standards facilities tailored to this segment.

- **Limited R&D in food processing machinery:** Experts point out the lack of grants for prototyping or higher TRL development in the food equipment sub-sector. They recommend programmes for equipment R&D (e.g., co-funded design projects, testing rigs, etc.). Of the current projects that have been sanctioned for technology development under ECIGSC, not one of them falls under food processing machinery[34]. While initiatives like the RDI fund recognise the need for R&D for competitive manufacturing, food equipment is not a focus area[35]. Therefore, startups and SMEs continue to face barriers in accessing funds and technical infrastructure. There are also no dedicated national testing labs for food machinery. Industry stakeholders have requested unified BIS/FSSAI standards and

CE/EHEDG-equivalent certification facilities. Without them, SMEs struggle to prove quality, deterring exports.

- **Reforming access to finance for MSMEs in the food processing machines sector:** Financing constraints emerged at two levels: the manufacturer's ability to invest in capability upgrades and the buyer's ability to procure equipment with confidence. Upgrading to high-precision equipment manufacturing requires capital expenditure on advanced machining, heat treatment, metrology, and quality systems. Stakeholders noted that such investments are difficult when access to long-tenor credit is limited and when working capital cycles are tight. The government should recognise this sub-sector as an application of advanced engineering and extend support similar to what has been offered for construction equipment.

- **Low coverage of quality control standards for food processing machinery:** With the goals of the National Manufacturing Mission seeking to position India as an indispensable part of GVCs, the quality aspect is as critical as cost competitiveness. In this context, Quality Control Orders (QCOs) are regulatory instruments that mandate conformity with the desired quality standards[36]. While the government has significantly enhanced quality control with ministries notifying 143 QCOs for over 720 products, India continues to have a limited number of equipment-specific standards compared to the extensive range covered by NSF/ANSI in the US and CEN EN standards in Europe, particularly for food machinery.

- **Lack of skilled workforce**: India's current food processing machinery industry is dominated by small and medium firms and few specialised skill areas—essential for modern food processing equipment—are available across the ecosystem. Advanced skills in design and hygienic engineering, mechatronics and controls, as well as quality control and service support, remain poor. While these skills are not unique to food machinery and are relevant for plastics, chemicals, or general fabrication, food-specific design practices require deliberate training and standard references.

- **Lack of inter-ministerial coordination:** Unlike flagship missions (like the Semiconductor Mission) or dedicated schemes (such as the Construction and Infrastructure Equipment (CIE) Scheme) , there is no single programme driving capacity in food processing machinery. The coordination across multiple relevant agencies is fragmented (MHI, MSME, MoFPI, MSDE, DPIIT, and state bodies). Several industry stakeholders called for a 'Mission on Food Processing Equipment' to integrate R&D, export promotion, and cluster development under one umbrella.

> "Buyer preference for foreign OEMs is often driven by perceptions around precision and material quality, highlighting the need to strengthen quality assurance, precision engineering, and brand credibility among Indian OEMs."
>
> **-Prof. H. N. Mishra, Emeritus Professor (Food Technology) - Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur**

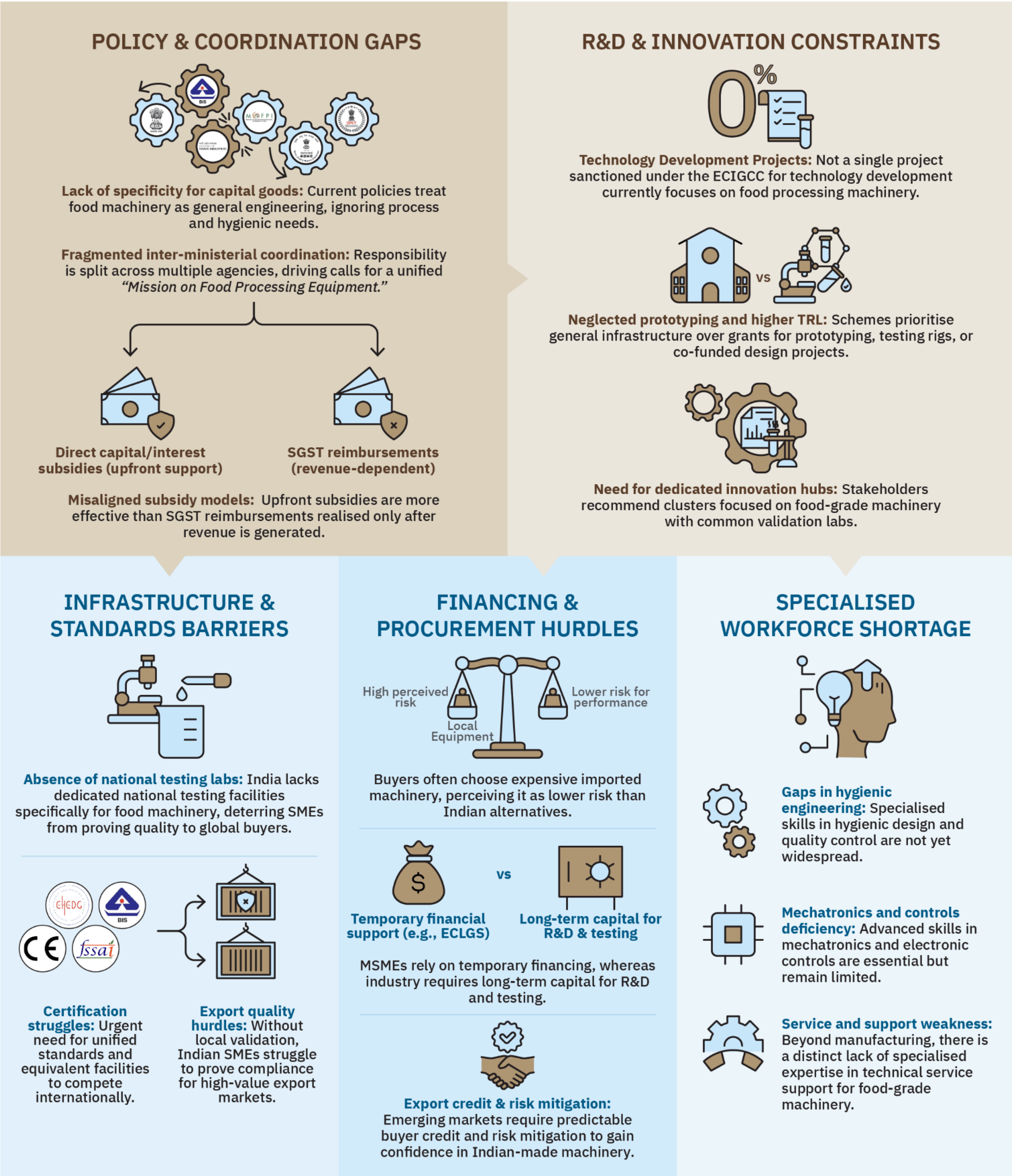


*Figure 11. Strategic gaps in India's food processing machinery sector*

Despite these gaps, the overall policy ecosystem has laid some groundwork. MSME cluster schemes and MoFPI initiatives are increasing the processing industry base (e.g., by establishing food parks and Kisan SAMPADA projects), which results in a bigger domestic market. For instance, processed-food exports grew from 13.7% to 20.4% of India's food exports between 2014–15 and 2024–25, implying more onshore processing.[37] Policymakers can leverage this existing momentum. While current schemes create demand for equipment, tailored adjustments (e.g., including machinery explicitly in PLI, supporting R&D, and streamlining regulations) will amplify their impact on the equipment sector.

### 6.2. The Tumkuru Machine Tool Park (TMTP) : An example of supporting capital goods sectors in India

The Government of Karnataka, recognising the opportunity in technology-led manufacturing, took the initiative to set up an integrated machine tools market with state-of-the-art industrial infrastructure. The TMTP has been developed over 530 acres of land as a self-contained gated community. Leveraging the benefits under the Enhancement of Competitiveness in Indian Capital Goods Sector (ECICGS) of the Department of Heavy Industries, Government of India, the state government invited participation from foreign companies/investors as well as domestic firms engaged in the manufacturing of machine tools to set up their units in this park. In addition to this, the common amenities, attractive incentives, and concessions are also available under the state's industrial policy. The project is intended to be a cluster of machine tool builders, makers of accessories, components and sub-systems, among others, and will help small and medium-scale enterprises to expand their manufacturing capacities[38].

The TMTP has 158 ready-to-build industrial plots of various dimensions. The park is fully developed with a proper layout, concrete roads, footpaths, drainage, electricity, water linkage and even bus shelters[39]. Over 115 acres of land have already been allotted[40]. TMTP is also situated opposite the emerging Japanese Industrial Township[41], ensuring the establishment of a technology-focused manufacturing ecosystem.

## 7. Recommendations

This study finds that India's opportunity in advanced food processing equipment is constrained less by the feasibility of fabrication and more by ecosystem challenges that are solvable with targeted action. The binding constraints include component-level import dependence, limited access to precision capability CAPEX, weak validation infrastructure, fragmented collaboration models, unevenly applied R&D pipelines, and underdeveloped service ecosystems. The recommendations below directly address these constraints and assign a clear primary stakeholder for accountability.

### 7.1. Supporting technological progress and domestic manufacturing

*7.1.1 Fund shared precision manufacturing and validation infrastructure around existing equipment clusters*

The most immediate barrier to moving up the performance curve is not basic fabrication. It is access to precision machining, balancing, metrology, and repeatability-oriented quality systems that require high upfront investment and high utilisation to be viable. Public co-funding of shared facilities anchored in existing clusters through the National Manufacturing Mission can give MSMEs and mid-sized OEMs access to advanced CNC time, rotor balancing, metrology, surface finishing, and control system test benches on a pay-per-use model. Creating shared infrastructure for validating precision machinery similar to what has been the template in the biomanufacturing sector can help MSMEs lower the CAPEX hurdle that currently prevents building and validating higher-capacity machines. An additional measure could be to include food processing equipment under the Technology Upgradation Fund, where existing food machinery MSMEs are encouraged to import advanced tooling equipment that can help them produce higher quality machines.

> "Without robust infrastructure for precision manufacturing and advanced material processing, India cannot localise the production of critical components, making targeted government support essential."
>
> **-Mr. Ranjit Pamo Lala, Managing Director & Director, Kilburn Engineering Ltd.**

*7.1.2 Establish a national OEM to MSME component matchmaking platform to accelerate localisation of equipment manufacturing value chains*

OEM requirements and MSME capabilities are often not aligned, particularly for high-tolerance parts and performance-critical subsystems. A national platform where OEMs can publish verified requirements with relevant technical details, qualification tests, and expected annual volumes can facilitate MSMEs with the right capability to submit their bids. Unlike a typical e-marketplace, this platform would allow for the development and production of highly customised and specific products. This converts localisation into a trackable pipeline of vendor development projects, reduces search and transaction costs, and supports faster domestic substitution for subsystems where lead time and serviceability drive buyer decisions. A matchmaking platform such as those developed by Industry Capability Network (ICN)[42] is an excellent example of government and industry working together to make supply chains more efficient and remove information asymmetries for businesses.

*7.1.3 Support establishment of dedicated advanced food machinery innovation clusters with a focus on machinery relevant for states based on their key agri-commodities*

Taking inspiration from the Tumkur Machine Tool Park initiative, the government should set up dedicated clusters for food processing machinery as well. Here, similar to the Government of Karnataka that took the initiative to establish the TMTP, the role of state governments becomes critically important. It is important to encourage major global producers of advanced food processing equipment to partner with Indian firms to create machinery manufacturing facilities through JVs wherever feasible. The focus should be on subsystems that materially affect cost, lead time, and uptime, including electronics and drives integration, gear train and rotating assemblies, vacuum and refrigeration subsystems, specialist seals and valves, and filtration modules and housings. This tackles import dependence at its root, which is supplier capability rather than assembly capacity. China is a great example that reflects the impact of such an intervention.

Depending on the major agricultural products of the states, a centrally funded initiative can support state governments to set up equipment parks that support the value-addition of those commodities. This helps modernise the equipment sector and propels India to strengthen the food processing industry and increase the volume of processing of agri-commodities, thereby reducing food waste and creating more jobs.

*7.1.4 Enable faster access to proven technology for critical subsystems from global technology providers*

The report identifies key technology gaps that exist among Indian equipment manufacturers of food processing machinery. The technology transfer from global players remains limited because the commercial case for domestic OEMs to build or acquire cutting-edge designs (that require upfront investment, patient capital, and a credible demand signal) is weak. Enabling faster and lower-risk access to proven subsystem technologies through licensing and co-development programmes that are explicitly tied to India-specific cost and performance targets can be a practical solution. To accomplish this at scale, the government must create a clear incentive package for domestic as well as foreign technology providers based on time-bound support linked to measurable localisation milestones, supplier qualification outcomes, and validated performance improvements.

*7.1.5 Form an industry association of companies in food processing equipments and adopt standards for non-differentiating parts, materials, and quality parameters*

Currently, most firms produce products that are widely different from each other, reducing economies of scale and slowing component localisation. An industry association can standardise non-differentiating and non-proprietary elements such as material grades, surface finish requirements, seal and valve specifications, fasteners, control cabinet architecture, and documentation templates. It can also create shared supplier audit protocols and approved vendor practices. This increases interchangeability, aggregates demand per part number, and makes supplier investment more viable. It also creates a unified interface with policymakers and labs for representation.

*7.1.6 Address the policy support gap by instituting a targeted programme for advanced food processing machinery and equipment*

The food processing equipment sector in India is primarily driven by MSMEs that are currently focusing on low-value-add fabrication and assembly work. They continue to be a major employer and contributor to the economy with production of food processing equipment for 2024-25 valued at over INR 15,200 Cr[43]. However, among all the subsectors of capital goods, it is the only one that has declined in value of production over the last decade. This phenomenon coincides with the rise of China as the major exporter of equipment to India. Similar to the dedicated scheme for construction equipment, a high-powered committee with key stakeholders from academic institutes, relevant ministries, and the private sector must be set up to look into India's relatively poor performance in this category of capital goods, and the committee should recommend a pathway to improve India's position as a global force in food processing machinery.

**7.2. Strengthening the accreditation and certification infrastructure for food processing machinery and components**

*7.2.1. Establish new certification labs and upgrade the existing facilities*

In addition to inadequate availability of testing labs, costs of testing different equipment and components in order to conform to the relevant standards of Indian Standards (IS) or international standards is very high in India. Regionally distributed labs should be set up near major manufacturing bases to test performance parameters identified as technical bottlenecks (in this study), including throughput stability, energy consumption, vibration and balancing compliance, controls and safety interlocks, and documentation readiness for regulated buyers. This can be done via government-aided testing facilities or by incentivising private investments through PPP for creating dedicated food machinery testing facilities. Additionally, the existing labs supported by the schemes of the Department of Heavy Industries do not have a distinct focus on food processing machinery. Besides setting up new laboratories, existing certification laboratories in institutes like NIFTEMs, CSIR-CFTRI and ICAR-CIPHET should also be upgraded.

> "India's thermal processing and drying equipment ecosystem is strong in basic engineering capability and cost competitiveness. However, to compete effectively at a global level, there is a clear need to strengthen precision manufacturing, increase adoption of advanced automation and process controls, and ensure consistent adherence to international quality, validation, and documentation standards."
>
> **-Mr. Ramesh S. Shinde, Director, Kerone Engineering Solutions Ltd.**

**7.3. Fostering R&D and creating pathways for industry-academia collaboration**

*7.3.1 Recognise research on advanced food processing machinery as a strategic area of national importance for India to reduce import dependence*

Start-ups and MSMEs in the food equipment space work with thin margins and do not have access to funds and infrastructure for R&D. Even in larger companies that have operations in India, R&D is low due to high costs and low returns on investment. Food equipment should be recognised as an eligible sector for receiving support under the RDI fund, and firms should be encouraged to develop product lines that meet international standards and can be alternatives for imported machinery. R&D should deliver solutions in (1) extrusion design for high-moisture products, especially screw elements and cooling die performance; (2) drying system integration, including energy recovery, safety architecture, and higher fidelity control improvements; (3) separation and filtration performance, especially membrane development and high-speed separation upgrades; (4) materials and wear parts, including qualified food contact seals and surface treatments that reduce fouling and improve durability; and (5) digital controls and monitoring, including diagnostics that improve uptime and reduce operator variability. Under this initiative, foreign companies should be encouraged to bring their innovation hubs to India.

*7.3.2 Incentivise MSMEs to collaborate on precompetitive R&D where demand is uncertain*

In emerging segments such as high-moisture extrusion performance elements, polymeric and ceramic membranes, critical rotating components, and advanced controls, individual firms underinvest due to uncertainty and limited validation capacity. Supporting pre-competitive collaboration through shared pilots, shared test data, and jointly defined benchmarks reduces duplication and accelerates learning. This directly addresses the report's diagnosis that low demand certainty pushes firms toward short-cycle fabrication rather than innovation.

*7.3.3 Eminent Institutions with expertise in food technology partner with promising private sector firms to establish centres of excellence for developing indigenous advanced technologies*

The Scheme for "Enhancement of Competitiveness in the Indian Capital Goods Sector" provides an excellent opportunity for food technology institutions and food processing machinery firms to collaborate on areas where India continues to be heavily dependent on imports. However, none of the CoEs sanctioned under both Phase I and Phase 2 focus on advanced food processing machinery. Given this scheme is demand-driven in nature, food technology departments in reputed institutions and the private sector must proactively leverage such schemes to bridge the technological gaps between Indian and foreign equipment manufacturers. While institutes like CIPHET develop indigenous machinery, especially for small-scale and rural applications, and CFTRI works on equipment design for food preservation, dehydration, and fortification, the focus on design and hygienic engineering, sensors, control systems, and integration remains low.

> "With targeted support from MoFPI, collaborations between academia and industry can create pilot and incubation centers that showcase new technologies and inspire broader investment."
>
> **-Dr. G. Arthaneeshwarar, Professor and Head (Department of Chemical Engineering), NIT-Trichy**

**7.4. Create a strong pipeline of workforce skilled in precision fabrication, automation integration, and equipment service**

*7.4.1 Set up of skilling training centres close to the existing and emerging equipment manufacturing clusters*

Under the Skill India initiative led by NSDC, training centres can be built under the PPP model in the established equipment manufacturing clusters as well as the upcoming ones to upskill the existing workforce and incoming workforce for both MSMEs and larger firms. Given the location of these training centres would be close to the clusters, trainees will receive hands-on experience as well as have the opportunity to be trained by industry professionals. Focusing on different shop-floor operations, quality control and maintenance, and design principles, along with building skills around supply chain management, servicing could be carried out by these centres. Food Industry Capacity and Skill Initiative (FICSI) can develop qualification packs for such training.

*7.4.2 Introduce new coursework and upgrade infrastructure in ITIs and polytechnics for food machinery-specific skilling*

Beyond engineering design, capability gaps persist in specialised execution, such as precision fabrication practices, automation integration, commissioning, and servicing high-pressure and high-speed rotating systems. ITIs and polytechnics offer basic training but lack specialisation in food machinery-specific disciplines. Introducing short courses on modular certifications and apprenticeship programmes designed with input from OEMs on design and hygienic engineering, mechatronics and controls, as well as quality control and service support that are aligned with global food safety standards (like HACCP and ISO 22000) will ensure a steady supply of skilled workers to the industry.

*7.4.3 Indian firms should build service as a core competitive advantage*

Very few Indian food equipment firms use technology to make their business processes, like procurement, distribution, marketing, and servicing, more efficient. Also, the use of techno-managerial processes like JIT, TQM, TPM, etc. is non-existent in most firms (except the very large ones). Downtime risk, spares availability, and service response repeatedly emerge as bottlenecks preventing buyers from adopting domestic equipment for high-value, uptime-critical operations. OEMs should treat service as a product through standardised spares catalogues, remote diagnostics, maintenance contracts, predictable response commitments, and field training for customer teams. Strong servicing capability reduces adoption friction for domestic equipment in high-value plants, creates recurring revenue, and stabilises cash flows that enable sustained investment in product improvement.

> "Without a common platform, MSMEs operate in isolation, weakening collective bargaining power and slowing knowledge transfer, highlighting the need for government-led engagement and coordination."
>
> **-Dr. Mahesh Kumar G, Associate Professor (Department of Dairy Engineering), Dairy Science College, Hebbal, Bengaluru**

**The way forward**

This report makes a simple point that is often overlooked in lengthy discussions about India's manufacturing capability. India already knows how to build machines. The next step is to make Indian machines the low-risk choice—first in India and then in export markets. That shift will not come from one major announcement or a single new scheme. It will come after a deliberate series of actions that converts today's capability into trusted performance in the future.

The most practical way to change buyer perception is to create a small set of credible reference deployments. This means real plants and real operating conditions and not just pilot runs. The goal is to generate simple, comparable evidence that domestic equipment can deliver stable output, predictable energy use, acceptable downtime, and clear maintenance routines. Once these references exist, three things become easier at the same time: (1) buyers commit faster, (2) lenders are more comfortable funding expansion, and (3) global partners take India more seriously as a manufacturing base.

In the next two years, the priority should be to create reference deployments, strengthen repeatability through better validation access, and build service systems that reduce downtime risk for early adopters. Progress should be measured through a small set of indicators such as the number of reference installations operating successfully, reduction in commissioning delays, improvement in documented performance consistency, and faster spares availability.

In the following three to five years, the focus should shift to scaling what works: expanding supplier qualification for critical parts, increasing standardisation of non-differentiating components, and using accumulated field data to close the remaining performance gaps. Export readiness then becomes a natural outcome of proven reliability, clearer documentation, and predictable service.

> "Significant R&D work is still required, and this calls for sustained funding and infrastructure support. Setting up infrastructure hubs or consortiums with indigenous manufacturers offers a practical approach to accelerate technology development."
>
> **-Dr. Roopa Banerjee, Senior Scientist – Biochemistry & Grain Food Quality, ICRISAT**

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