An International Multidisciplinary Journal
अनन्यशास्त्रम्
(A Unique Treatise of Knowledge)
ISSN:3049-3927 (Online)
Volume: 01 | Issue: 03 | December: 2025
Research Article

ANANYAŚĀSTRAM:
An International Multidisciplinary Journal
(A Unique Treatise of Knowledge)
Peer-Reviewed | Refereed | Open Access Journal
DOI: https://doi.org/10.64328/aimjv01i030022

Regulating the Journey: A Socio-Legal Analysis of Transportation's Impact on Food Shelf-Life, Safety, and Consumer Protection

Dr. Vartika Sxaena[1] and Shilpi Jadon[2]

Abstract

The article critically examines the socio-legal aspects of food transportation in India and focuses on the direct & indirect effects on safety rules and shelf life of consumer protection. This study evaluates how technical limitations, regulatory fragmentation, and insufficient infrastructure compromise food integrity during transit based on recent enforcement patterns in the year 2021-2025 and statutory structure under the Food Safety and Standards Act, 2006. The analysis uses comparative insights from international regimes such as the FDA (USA) AND EFSA (EU) to highlight best practices in cold chain logistics, traceability and legal accountability. Using both doctrinal and empirical approaches, the paper evaluates the effectiveness of India's current regulatory framework, including the FSSAI's licensing, inspection, and penalty system, and identifies critical areas for improvement. Furthermore, it investigates how digital solutions such as blockchain and IoT and Public-private partnerships could lessen food deterioration caused by transportation. Ultimately, the study governance prioritises consumer welfare, producer equality, and sustainable logistics.

Keywords: Food Safety and Standards Act (FSSAI), Shelf-Life Regulation, Cold Chain Logistics, Consumer Protection Law, Transportation and Logistics.

Introduction

"Transport is not just the movement of goods—it is the movement of freshness, safety, and trust in every bite of food we consume." In India, Food Transportation is a crucial part of the food supply chain. Now, it has become very essential that products reach to consumers safely with safety precautions. A Primary Role of transportation food is to move food items from one location to another. Moreover, the transported food includes two kinds: perishable food (fruits and vegetables, Dairy Products, Meat, and Seafood) and semi-perishable food (Bread, Pastries, Paneer, Noodles, and Maggie). The nature of perishable food is sensitive to time, temperature and humidity. On the other hand, they have a little longer shelf life, but improper

[1] Assistant Professor, Department of Law, Faculty of Law, Amity University Madya Pradesh, Gwalior, India, Email: vsaxena1@gwa.amity.edu , https://orcid.org/https://orcid.org/0000-0002-4857-4009
[2] Research Scholar, Department of Law, Amity University of Madhya Pradesh, Gwalior, India, Email: 2000singhshilpi@gmail.com, https://orcid.org/0009-0002-8806-608

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transportation can cause them to spoil. The primary goal of food transportation is to safeguard the authenticity and shelf life of food products during transportation. The term "shelf-life" describes how long a food product is safe to eat under specific storage circumstances. The product's shelf life is initiated at the time of production or packaging and lasts until it is no longer fit for human consumption, either because of deterioration or spoilage. Perishable items, such as meat, dairy, fruits, and vegetables, usually pose a high risk and are more susceptible to microbial activity, moisture, and temperature changes. Even non-perishable products, such as dry goods or canned foods, can deteriorate over time due to oxidation, moisture absorption, or poor packaging. utilization of specialised transportation technologies, like shielded packaging and cold chains, together with rigid observance of time, temperature, and hygiene regulations. Maintaining shelf-life and safety has become a major legal, logistical, and societal challenge due to worldwide trade and the rising demand for fresh food; this calls for cooperation between food producers, transporters, regulatory agencies, and consumers. In addition to improving food's shelf life, timely, sanitary, and effective transportation is essential for consumer safety, food waste reduction, and preserving customer trust in the food supply chain. From the perspective of the Socio-legal dimensions of food transportation, good quality food, with the proper packaging, and ensuring safety, is becoming a significant part, which is directly affected, and drastically reduces shelf life, but it also violates the rights of consumer (right to safe and quality food) it comes under the Consumer Protection Act, 2019 and Food Safety & Standard Act, 2006. Furthermore, a consumer has the right to a public interest lawsuit.

Affectors of shelf-life through impact and improper transportation:

Transportation plays a vital part in preserving or deteriorating the quality and safety of food products during their complex journey from farm to consumer. In India's vast agricultural landscape, where the sector contributes 17.9% to GDP and employs nearly half the population, transport inefficiencies have particularly severe consequences. Although transportation makes it easier to reach markets, jobs, education and services, it also poses serious dangers to food products, which directly affects their shelf life and, ultimately, their safety for ingestion. To improve supply chain resilience and guarantee public health, it is essential to comprehend the particular elements that jeopardize food integrity during transportation within India’s distinct regulatory and infrastructure framework.

Essential Factor That Reduces Food Shelf-Life in India During Transit. Food Shelf-life is shortened during transportation due to some important variables, which frequently result in large post-harvest losses and food waste- problems that are especially severe in India’s expanding cold chain infrastructure.

a. Misuses of Moisture Fluctuations and Temperature:

In India’s many climatic zones, temperature continues to be the most important factor affecting quality and shelf life. Transportation problems are made worse by the country’s significant temperature fluctuations, which range from hot summers that surpass 45 degrees Celsius in the northern plains to high humidity levels in coastal areas. 17.9% of India’s GDP comes from the agriculture sector, which is a major contributor to the

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economy. These issues are made worse by India's poor cold chain infrastructure. Although the nation has over 8.38 lakh MT of cold storage capacity, it is still not enough to handle the number of perishables generated. Temperature excursions are caused by a variety of factors, including fluctuating outside temperatures, ineffective cooling systems, long travel durations across long distances, and procedures like transporters shutting off cooling units to save fuel. The "temperature danger zone" can quickly shorten the shelf life of chilled goods that are popular in Indian marketplaces, such as fresh fruits, dairy products, and green vegetables. Furthermore, difficulties arise during the monsoon season, when temperature swings and high humidity

levels- which frequently surpass 80%- cause serious moisture-related damage. During the dry season, high temperatures and low relative humidity lead to significant water loss through transpiration in fresh produce, resulting in wilting and decreased moisture content. This is especially problematic for India's extensive production of high-water-content vegetables, such as tomatoes, cucumbers and leafy greens.

Infrastructure Challenges: Improper Handling and Mechanical Damages:

In India's post-harvest supply chain, mechanical damage is a major issue that results in significant economic and market-value losses. Approximately 40% of rural roads in India are unpaved or poorly maintained, which causes significant vibration and jolting during transportation, despite improvements in the country's road infrastructure.

Due to a lack of awareness and training among farm workers and transporters, poor handling practices are nevertheless common. Produce tissues can be deformed and damaged by compression forces from overstocking vehicles, a frequent practice to optimize load efficiency, given high transportation costs. The traditional practice of using jute bags or basic plastic crates without adequate cushioning exposes produce to impact forces during loading and unloading at busy mandis. Vibration during transit on India's often rough roads causes physiological alterations in produce, including peel softening in mangoes and bananas, color changes in tomatoes, and reductions in cell wall integrity across various fruits and vegetables.

Insufficient Packaging and Cold Chain Integrity Failures:

India's packaging standards for fresh produce lag behind international best practices. Traditional packaging methods, such as loose loading in trucks or using non-standardized containers, compromise product integrity. Poor seal integrity in available packaging allows ingress of dust, moisture, and pathogens, accelerating spoilage in India's often dusty transport corridors. Cold/refrigerated storage facility. Food Product transporter with a variety of specialized vehicles, including milk tankers, food trucks, insulated refrigerated vans and wagons, and more. Even though FSSAI regulations mandate the use of specialized trucks for food delivery, enforcement is still uneven, especially in rural areas where the majority of produce comes from. The efficiency

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of cold chain packaging is frequently undermined by a lack of uniformity and quality control, especially when the packaging must endure India's difficult transportation conditions.

Time delays and ineffective operation :

Food waste is greatly increased by India's complicated logistics system, which prolongs transit times and shortens product shelf life. The following elements are specific to the Indian Context:

i. The traditional mandi (wholesale market) system, while providing price discovery, often creates significant delays as produce waits for auction and subsequent distribution. During peak harvest seasons, trucks may wait for days before unloading.
ii. Multiple state border checkpoints, despite the implementation of GST and e-Way Bills, still cause delays as vehicles undergo inspections and documentation verification. These delays are particularly damaging for highly perishable items during hot weather.
iii. India's major transportation corridors, particularly around metropolitan areas like Mumbai, Delhi, and Bangalore, experience severe congestion that significantly extends transit times. The lack of dedicated cold chain corridors exacerbates these delays.
iv. Religious festivals and monsoon seasons create predictable but severe logistical disruptions, with transport availability reduced and transit times extended during critical periods.

Pollution Risks in Transportation Systems:

India faces particular issues due to its varied transportation environment. Despite laws, mixed freight loading where food items share space with non-food products remains widespread. In the vegetable supply chain, when many types are delivered more frequently, cross-contamination between different food items happens regularly in shared vehicles.

Many food transporters lack the necessary cleaning procedures, and unhygienic vehicle conditions are common. Produce that is physically damaged during India's difficult transportation conditions is more vulnerable to bacterial and fungal contamination because wounds serve as entry routes for diseases that are common in the country's tropical climate.

Impact on India's Sustainable Economy, Consumer Health, and Food:

In India's particular market environment, the aforementioned elements have significant effects on food quality, consumer trust and economic feasibility.

1.1.The Impact of Nutritional Detriment on Human Health:

Inadequate transportation conditions significantly reduce nutritional content, which is a serious problem in India, where malnutrition persists despite sufficient food production. High humidity and temperatures drastically lower vital phytonutrients like carotenoids and ascorbic acid (Vitamin C) in plants that are

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important to Indian diets, such as spinach, amaranth, and other leafy greens that are mainstays in regional cuisines. Given the high prevalence of anaemia and vitamin shortages in India, where fresh food is a vital source of important nutrients for the bulk of the population, this nutritional degradation is especially troubling.

1.2.Temperature Challenges in Food Safety and Fungal Spoilage:

When transport temperature control fails, India's tropical and subtropical climate zones provide the perfect environment for faster microbial development. The main issue is temperature abuse, which creates circumstances for exponential bacterial development and is especially problematic for commodities high in moisture and protein that are popular in Indian marketplaces, such as meat, dairy products, and fresh fruits. Temperature management is essential for public health since foodborne pathogens like Salmonella and E. coli are frequent in Indian environments.

1.3.Consumer Trust and Marketability:

In India's price-sensitive marketplaces, visual quality continues to be a major factor in customer purchasing decisions. Decay, browning, and wilting are examples of spoilage signs that drastically lower marketability in conventional retail settings where customers examine the product in person before making a purchase. Indian consumers are becoming more demanding of international quality standards, especially in metropolitan areas, which makes transportation-related damage more detrimental to business. Customers become dissatisfied and lose faith in brands and merchants as a result, which affects their propensity to make repeat purchases in marketplaces where recommendations from friends and family have a big impact on purchasing decisions.

1.4.Economic Losses:

In the context of India, the economic consequences of inappropriate food transportation are very dire. Around 30-40 % of total fresh produce experiences post-harvest losses, with the primary focus of the agriculture and food sector always being on increasing yield and productivity, but resources are limited, and there should be a focus on managing food loss and waste, which is almost around 30%. For India's smallholder farmers—who constitute over 85% of agricultural producers—products rejected due to transport-related damage represent direct income losses that can be devastating to livelihoods. The National Sample Survey Office estimates that post-harvest losses in fruits and vegetables alone cost the Indian economy over ₹92,000 crores annually, with transportation inefficiencies being a major contributing factor.

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The scale of economic impact extends beyond direct losses:

Figure No. 1: Examining Supply Chain Issues in the Fresh Product Sector in India

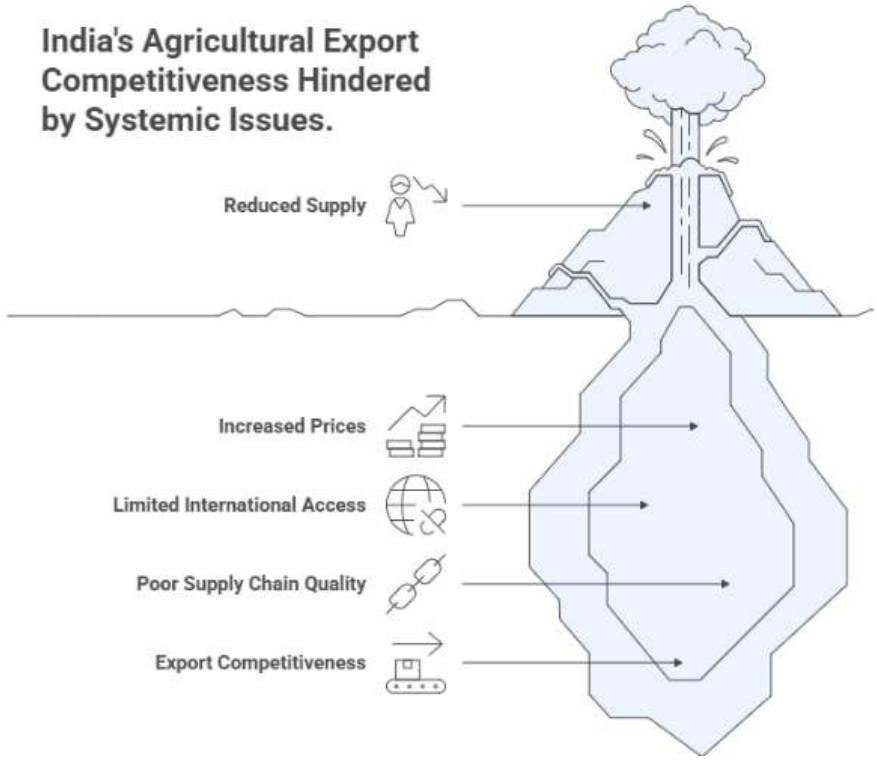

Figure No. 2: Analyze India's Agriculture Export

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1. Indian compliance framework and fssai in the legal & regulatory landscape:

India's food supply chain integrity, specifically in the transportation context, is largely determined by the regulatory framework set under the Food Safety and Standards Authority of India (FSSAI). As the single regulator for food at the topmost level, FSSAI has a mandate that covers the entire value chain of food, including production, storage, transport, and distribution. With major ramifications for consumer rights, public health and the liability of food business operators (FBOs), ensuring food safety and quality through transit is not only a technical challenge but also a legal need. Using statutes, rules, case laws, and factual data, this section critically analyzes the FSSAI's regulatory structure, state-level enforcement, and the legal ramifications of non-compliance

FSSAI Transportation Requirements:

The Food Safety and Standards Act, 2006 (FSSA), and the Food Safety and Standards (Licensing and Registration of Food Businesses) Regulations, 2011, form the statutory basis for food safety in India. The regulatory scope of the FSSAI includes the transport of food conspicuously, acknowledging that this stage is a significant control point for shelf-life as well as safety. Medium-sized traders, transporters, and wholesalers, that is, FBOs with an annual turnover between ₹12 lakh to ₹20 crore, need to have a state license under the FSSAI regime. This requirement of a simultaneous state license is not nominal; rather, it is aimed at exercising regulatory control under the size and risk profile of the operator. Transport vehicles used for the carriage of food have to meet certain hygiene and temperature control requirements. For perishable foods, this entails the use of chilled or insulated vehicles and keeping temperature logs, as laid down in Schedule 4 of the Licensing Regulations. The FSSAI has laid down specific guidelines on cleaning and sanitizing transport vehicles, discouragement of mixed loads (e.g., raw meat with ready-to-eat foods), and the utilization of food-grade packaging materials. Throughout the transportation procedure, accurate documentation is required. Food safety officers are required to inspect FBOs' records of food consignments, temperature logs, cleaning schedules, and incident reports. Transporters can use the Food Safety Management System (FSMS) templates from the FSSAI as model documentation standards. Food safety training in FSSAI-approved programs is required for workers involved in food transportation. One of the main flaws in the supply chain is addressed by the Food Safety Training and Certification (FoSTaC) program, which focuses on raising awareness and increasing capacity among transportation personnel.

Regulation and Enforcement Challenges at the State Level. The federal structure of India makes it extremely difficult to implement food safety regulations. There is a lot of diversity in compliance levels and enforcement intensity because state food safety authorities are responsible for enforcement, even though the FSSAI provides the overarching regulatory framework.

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Strong enforcement mechanisms, including regular inspections, mobile food testing facilities, and active monitoring, have been put in place by states like Maharashtra, Gujarat, Karnataka, and Tamil Nadu. For example, Maharashtra has led the way in using digital platforms for

licensing and complaint resolution, which has raised compliance rates (Maharashtra FDA Annual Report, 2022). States with little funding or a lack of regulatory attention lag in monitoring, which causes problems with interstate transporters' compliance. A further layer of regulation is provided by various states' Agricultural Produce Market Committee (APMC) Acts. It may be redundant and inconsistent for transporters to regularly undergo both FSSAI and APMC licensing. Although the Farmers' Produce Trade and Commerce (Promotion and Facilitation) Act, 2020 and other recent central government initiatives to open up agricultural markets have attempted to reduce these obstacles, inconsistent implementation and regulatory uncertainty still exist in many areas.

STATE/UT	KEY CHALLENGES
Maharashtra	61% vacancy in Food Safety Officer (FSO) posts; limited lab capacity
Uttar Pradesh	55% FSO shortfall; weak inspection coverage; delayed prosecutions
Jharkhand	93% FSO vacancy rate; enforcement machinery nearly non-functional
Bihar	Poor testing infrastructure; lack of NABL-accredited labs
Delhi (NCT)	High vendor density; enforcement bottlenecks due to limited manpower
Tamil Nadu	Better compliance, but suffers from procedural delays and overlapping jurisdictions
Punjab & Haryana	Strong agricultural base, but weak surveillance and consumer empowerment metrics
North Eastern States	Infrastructure gaps, low awareness and training, and minimal digital enforcement tools

Table No. 1: State-Wise Enforcement Challenges Under FSSAI

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Key Offences and Penalties :

Food safety is regarded very seriously in Indian law, as seen by the severe legal repercussions for transportation violations of FSSAI regulations. The FSSAI (Penalty) Regulations, 2011, and the parent legislation FSSA, 2006, list a variety of sanctions.

- Financial sanctions are most prevalent, with penalties from ₹25,000 for minor offences (e.g., inadequate documentation) to ₹10 lakhs for major offences (e.g., compromising public health through unsafe transport conditions). For repeated or serious offences, the FSSAI can suspend or cancel the operating license of the transporter or FBO permanently. The Supreme Court of Centre for Public Interest Litigation v. Union of India (2013) reaffirmed the principle that regulatory bodies have to act with utmost promptitude in safeguarding public health and issuing a suspension of license if necessary.

- Criminal liability can follow where non-compliance leads to outbreaks of foodborne illnesses or consumer injury. Section 59 of the FSSA, 2006, prescribes imprisonment and a fine where the breach of food safety leads to harm or death. The Nestlé India Ltd. v. Food Safety and Standards Authority of India (2015 Maggi noodles case) is representative: recall and temporary ban of Maggi products were followed by criminal action against company officials for violating food safety norms, among other things, such as misleading labels and non-compliance with ensuring product safety during transportation and distribution.

- Business shutdown is the ultimate penalty, reserved for those cases where offences are so egregious as to present a continuing risk to public health. The FSSAI has invoked this option in cases of pervasive non-compliance, specifically in the unorganized sector.

An important element of compliance is the labelling of packaged food items. The Food Safety and Standards (Packaging and Labelling) Regulations, 2011, mandate displaying "Best Before" or "Use By" dates that are enforceable by law. Transporters selling or distributing food products after the date of expiry are subject to prosecution, as established in Ramesh Kumar v. Commissioner of Customs (2017), wherein the Delhi High Court confirmed penalties against a transporter for distributing expired milk products.

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SECTION	OFFENCE DESCRIPTION	PENALTY IMPOSED	NOTABLE CASE(S)
50	Sale of food not of the demanded nature/quality	Up to ₹5 lakh (₹25,000 for petty manufacturers)	State of Maharashtra v. Hindustan Coca-Cola Beverages Pvt. Ltd. – mislabeling issue
51	Manufacture/sale of sub-standard food	Up to ₹5 lakh	FSSAI v. Raj Dairy Products – sub-standard milk sample penalized
52	Misbranded food	Up to ₹3 lakh + possible destruction of goods	PepsiCo India Holdings Pvt. Ltd. v. FSSAI – packaging dispute
53	Misleading advertisement	Up to ₹10 lakh	Horlicks Ltd. v. Zydus Wellness Ltd. – misleading health claims
54	Food containing extraneous matter	Up to ₹1 lakh	FSSAI v. Local Vendor (Delhi) – insect found in packaged snack
55	Failure to comply with FSO directions	Up to ₹2 lakh	FSSAI v. Hotel Saravana Bhavan – non-compliance with hygiene directives
56	Unhygienic processing/manufacturing	Up to ₹1 lakh	State v. Krishna Bakery (UP) – unhygienic kitchen conditions
57	Possession/manufacture of adulterants	₹2 lakh (non-injurious); ₹10 lakh (injurious)	Centre for Public Interest Litigation v. Union of India – SC directed stricter penalties
59	Unsafe food causing injury or death	Imprisonment up to life + fine up to ₹10 lakh	Nestlé India Ltd. – Maggi Noodles Case – lead content controversy
60	Repeat offences	Double penalty or license cancellation	FSSAI v. Multiple Repeat Offenders (Punjab) – license revoked for repeated violations

Table No. 2: Key Offences and Penalties

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Regulatory Effectiveness and Issues:

Considering the FSSAI framework's comprehensiveness, empirical research and enforcement statistics show ongoing difficulties. Transportation-related breaches made up 18% of all food safety violations, with the perishable foods industry having the highest prevalence, according to the FSSAI's Annual Report (2023). Compliance with temperature control regulations is compromised by the absence of consistent cold chain infrastructure, particularly in rural and semi-urban locations. Additionally, the numerous regulatory organizations, including the FSSAI, state food safety administrations, and APMC boards, increase transporters' perplexity and compliance expenses. Customers now have more rights to file complaints regarding food safety violations, including transportation defaults, thanks to the Consumer Protection Act of 2019. However, the effectiveness of these solutions depends on early discovery, reporting, and enforcement, where systemic lags and resource availability remain significant obstacles.

Indian case studies:

Despite its vastness and diversity, the Indian food value chain is very vulnerable to transportation failures that negatively impact food safety, shelf life, and economic value. The multifaceted character of transportation breakdowns and the evolving technology and regulatory remedies are reflected in recent high-profile examples in a variety of commodities and regions. Four such incidents are closely examined in this part, each of which describes different failure patterns, regulatory reactions, and industry adjustments.

Case Study 1: Mango Export Losses from Maharashtra

The 2019 export season dealt serious damage to Maharashtra's Alphonso mango, which is highly sought after in both domestic and foreign markets. Over ₹50 crores in lost revenue resulted from the rejection of exports intended for Europe at destination ports. The Agricultural and Processed Food Products Export Development Authority (APEDA) and FSSAI conducted a thorough investigation and discovered a series of transportation failures. Pre-cooling facilities were either nonexistent or inadequate at the Ratnagiri collection stations, compromising the fruit's original quality before transportation. Temperature excursions caused by malfunctioning refrigerated trucks during road transit to Mumbai airport violated both APEDA's export procedures and FSSAI's Schedule 4 sanitary regulations. The issue was made worse by additional delays at airport cargo terminals, which exposed the mangoes to more temperature abuse. Furthermore, packing was found to be inadequate for the lengthy transit times and uneven handling circumstances typical of air freight to Europe. The consequences extended beyond immediate financial losses. With several exporters losing their European accreditation and having to undertake costly re-auditing, India's reputation as a reliable exporter of high-quality mangoes was damaged. This also prompted a regulatory response: FSSAI mandated stricter monitoring for fresh fruit headed for export, including the use of temperature recording devices for valued shipments. These provisions were later included in the Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011, and implemented through joint inspection by FSSAI and APEDA.

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Case Study 2: Milk Tanker Contamination Incident in Gujarat

In 2020, a leading dairy cooperative in Gujarat was compelled to recall large volumes of milk following the detection of bacterial contamination during routine quality checks. The contamination was traced to a series of transportation failures, as documented in the FSSAI's Annual Surveillance Report, 2021. The tankers employed for collecting milk were not properly cleaned between routes, breaking the hygiene requirements of the Food Safety and Standards (Licensing and Registration of Food Businesses) Regulations, 2011. Temperature regulation while in transit from collection centres to the processing plant was not uniform, with many tankers having non-functional cooling systems. Worryingly, a few tankers were used to transport non-food liquids in the past, causing cross-contamination, a blatant violation of Section 26 of the Food Safety and Standards Act, 2006, which forbids the use of food transport vehicles for carrying non-food substances.

Though the process of pasteurization carried out at the processing units saved the country from a large-scale public health scare, a few consumers experienced slight gastric infections, causing market confidence to temporarily dip. FSSAI levied fines amounting to ₹2.5 crores on the cooperative and ordered full vehicle sanitization protocols to be put into place. Three transport contractors had their licenses revoked for life under Section 32 of the Act. The case emphasized the crucial role of documentation: the lack of adequate cleaning and sanitization records was central to regulatory action taken.

Case Study 3: Vegetable Supply Chain COVID-19

The 2020 countrywide COVID-19 lockdown provided a rare, if not unintended, experiment on the impact of transport disruption on the supply chain in food. Vegetable transport from production centers in Karnataka and Tamil Nadu to urban markets like Bengaluru, Chennai, and Mumbai was severely impacted by bureaucratic delays in securing movement permits for basic commodities. In spite of government exemptions, border check posts and a limited availability of transport resulted in overloading of available vehicles and multi-day transit delays. Shortages of labour also impeded loading and unloading at origin and destination points.

Government estimates, as cited by the Ministry of Agriculture and Farmers Welfare, showed that more than 60% of perishable fruits and vegetables spoiled in transit or at warehouses during the initial month of lockdown. City consumers saw their prices for vegetables jump by 200–400%, with no recompense to farmers for destroyed produce. The event spotlighted the vulnerability of conventional transport networks and hastened the take-up of direct farmer-to-consumer models, including online platforms and cooperative delivery schemes. Regulatory agencies, such as FSSAI and state food safety authorities, later issued emergency movement guidelines for perishables and prioritised the creation of digital permit systems for future emergencies.

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Case Study 4: Potato Storage and Transport Failures in West Bengal

West Bengal, which produces almost a quarter of India's potatoes, suffered disastrous losses during the 2021 harvesting season. Transport-related accidents accounted for almost 40% of the total waste, and the combination of storage and transport failures resulted in estimated farmer losses of ₹800 crores. The fundamental quality of potatoes housed in conventional cold storage warehouses was compromised by frequent power outages throughout the busiest summer months. Due to the lack of refrigeration in the transport vehicles used to move potatoes from storage to markets, tubers were exposed to high ambient temperatures and mechanical damage from overloading. Road building projects extended transit times, which increased spoiling levels even further. The financial impact was catastrophic: West Bengal farmers suffered financially as potato prices surged 150% in Delhi and Mumbai marketplaces due to a decline in supply. During the crisis, both the public and commercial sectors invested in mobile cool stores and developed transport containers designed specifically for potatoes that were adapted for Indian highways. The National Horticulture Board and the Ministry of Food Processing Industries financed these innovations, demonstrating a growing recognition of the need for location-based solutions.

Reviewing how the regulations in other countries affect the transportation of shelf life:

Since transportation can have a major impact on the shelf-life and integrity of food products, a harmonized regulatory framework is necessary to ensure both safety and quality in the worldwide movement of food commodities. In this backdrop, the regulatory regime and practical set-up in India concerning food transportation, shelf-life, and safety must be compared and contrasted with other large jurisdictions, e.g., the European Union (EU), the United States of America (USA), and other developed economies. Such comparative analysis is based on the international standards laid down by the Codex Alimentarius Commission and the legal obligations arising from the WTO agreement, especially the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT).

International Standard:

At the heart of international food safety regulation is the Codex Alimentarius: myriad guidelines, standards and codes of practice set up by the FAO-WHO Joint Committee. Codex covers aspects of food safety related to levels of additives, contaminants, pesticide residues, hygiene, and labelling. Being voluntary standards, Codex may not be enforceable under national law; however, the WTO elevates their status to being considered the international reference for food safety. Thus, the SPS Agreement directs WTO Members to base their sanitary and phytosanitary measures on standards, guidelines, and recommendations, referring in food safety to the Codex as the relevant standard-setting body.

National regulations consistent with Codex standards are presumed to conform with the SPS Agreement, and in a case of food trade dispute, the Codex standards shall become the point of reference. However, the member

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countries are entitled to apply more stringent measures, upon the condition that they can be justified scientifically and shown to be necessary for the appropriate level of protection of human life or health. Harmony is encouraged through this framework, together with discretion being allowed to individual countries based on public health priorities and risk assessment considerations.

1.1.Specific Country Approaches:

European Union (EU):

The EU operates under an extensively harmonized system where food is taken into consideration for safety, especially during transportation. Regulation (EC) No. 178/2002 sets out the general principles and requirements of food law, including traceability of food at all stages of production, processing, and distribution. In the course of transportation, the EU regulates temperature strictly, primarily for perishable goods, and enforces the use of advanced transport equipment. The Rapid Alert System for Food and Feed (RASFF) is designed in such a way that it instantly relays information and actions regarding food safety occurrences so that unsafe products can be swiftly identified and removed from the market.

United States of America (USA):

The biggest thing under the regulatory umbrella in America is the Food Safety Modernization Act (FSMA); this act changes the entire paradigm from being reactive to food safety management to being preventive. The FSMA requires risk-based inspections and imposes control over virtually all types of imported food. It also regulates food transportation under the Sanitary Food Transportation Act. Food traceability is ensured through record-keeping requirements, while the Food and Drug Administration has wide powers to detain and recall unsafe food.

India:

India's food safety regime is governed by the Food Safety and Standards Act, 2006, and implemented by the Food Safety and Standards Authority of India (FSSAI). The FSSAI sets standards for food products, including those relating to shelf-life, labelling, and transportation. India has increasingly aligned its regulations with Codex Standard, particularly in the context of international trade. Risk profiling, import clearance, and non-compliance penalties are all part of the regulatory system. Challenges persist in enforcement, infrastructure, and capacity, most visibly in the cold chain and transport industries. One high-profile case, the recall of Maggi noodles in 2015, has made it very clear that both the weaknesses and strengths of the Indian system for handling food safety crises were on display.

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1.2.Case Studies:

European Union: In Germany, the 2011 E. coli outbreak (Escherichia coli O104:H4), which was traced through the RASFF system, demonstrated the efficacy of the EU's traceability and rapid response mechanisms. Additionally, the capacity to promptly locate and isolate the source of contamination reduced the negative effects on public health and rebuilt consumer trust.

The United States of America: The 2018 romaine lettuce E. coli epidemic (E. coli O157:H7) in the USA demonstrated the advantages and disadvantages of the FSMA framework. Although a nationwide recall was made possible by the FDA's traceability rule, calls for improved digital traceability resulted from the supply chain's complexity, making it difficult to identify the source of contamination.

India: The Nestlé India Ltd. v. Food Safety and Standards Authority of India (Maggi Noodles Case) is a prime example of the country's disregard for rules and enforcement. In addition to highlighting the significance of thorough testing and enforcement, the FSSAI's decision to recall Maggi noodles owing to excessive lead levels also exposed deficiencies in laboratory facilities, agency coordination, and public communication.

Australia: An intriguing case study of implementing a unified, science-based regulatory framework may be seen in Australia's response to the 2018 Listeria outbreak from rock melons. Food Standards Australia New Zealand (FSANZ) and state health agencies worked together to quickly determine the epidemiological cause of contamination, immediately recall affected items across the country, and communicate openly and honestly with the public. This strategy, which is based on the Food Standards Australia New Zealand Act 1991 and is integrated into a robust traceability and risk management system, was able to contain the outbreak's negative effects and foster public confidence in Australia's food safety governance framework with regard to responsiveness and integrity (FSANZ, 2018).

India's Approach's Advantages and Drawbacks:

A comparison of the legal frameworks governing the transportation of commodities with short shelf lives reveals both notable advancements and persistent difficulties in the Indian setting. India's enforcement framework is still less robust than that of the European Union (EU) and the United States (USA), despite the Food Safety and Standards Authority of India (FSSAI) having established a solid institutional and statutory foundation based on the Food Safety and Standards Act, 2006, and bolstered by ongoing regulatory revisions. The EU's harmonized regulations, such as Regulation (EC) No 178/2002 and the Rapid Alert System for Food and Feed (RASFF), offer consistent traceability, prompt incident response, and uniform recalls throughout member states. Preventive controls, risk-based inspections, and electronic traceability are all mandated by the USA's Food Safety Modernization Act (FSMA), which is supported by centralized federal oversight.

On the other hand, the State Food Safety Index 2022-2023 highlights how India's federalism causes significant disparities in state-level enforcement, with even the best-performing states having low scores in the categories

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of food testing infrastructure and compliance. The lack of a national traceability system highlights the disparities and makes it more difficult to facilitate prompt recalls and adequate consumer protection when food safety concerns arise. The 2015 Maggi noodles recall is noteworthy because, although the FSSAI acted quickly to remove potentially dangerous goods from store shelves, the incident revealed shortcomings in lab capacity, interagency cooperation, and response time in comparison to international best practices.

However, public awareness and regulatory changes have been sparked by high-profile events like the Maggi recall. In order to improve real-time monitoring and data exchange between enforcement agencies, FSSAI has since increased inspections, particularly for high-risk food businesses. It has also introduced electronic compliance and surveillance platforms, such as the Food Safety and Compliance System (FoSCoS) and Indian Food Laboratories Network (INFoLNet). Along with equipping itself with mobile laboratories for food testing and training food safety officials, the federal government has also issued directives to standardize sampling, testing, and enforcement actions among states. Food safety regulations have improved slightly as a result of these actions, but there are still issues with consistency and effectiveness across the nation.

Identifying Key Changes, Challenges, and Regulatory Defects:

The data analysis reveals many significant patterns. First, temperature abuse is still the most common cause of food spoiling during transportation globally, but it is considerably more common in India due to poor infrastructure and inconsistent regulation. Second, both increased awareness and ongoing structural weaknesses are contributing to an increase in consumer complaints. Even with technical advancements and legislative changes, the relatively high number of complaints in India suggests that enforcement is not keeping up with the complexity of modern supply chains.

Third, despite its increased strength, regulatory enforcement activity is still primarily reactive rather than preventive. While the introduction of digital complaint portals (E-daakhil) and mobile food testing laboratories is are commendable initiative, they must be accompanied by active surveillance, real-time monitoring, and harsh consequences for noncompliance. Although redressal channels have been strengthened by the Consumer Protection Act of 2019, prompt settlement and compensation remain issues, especially for marginal and rural consumers.

Through uniform regulations, cutting-edge infrastructure, and stringent enforcement, the EU and the USA have achieved reduced levels of transportation-related pollution globally. Traceability, quick recall, and preventive controls are exemplified by the USA's FSMA program and the EU's RASFF scheme. India's efforts to establish cold chain infrastructure and align with Codex requirements are commendable, but more work is needed in the areas of interagency coordination, industry training, and capacity-building.

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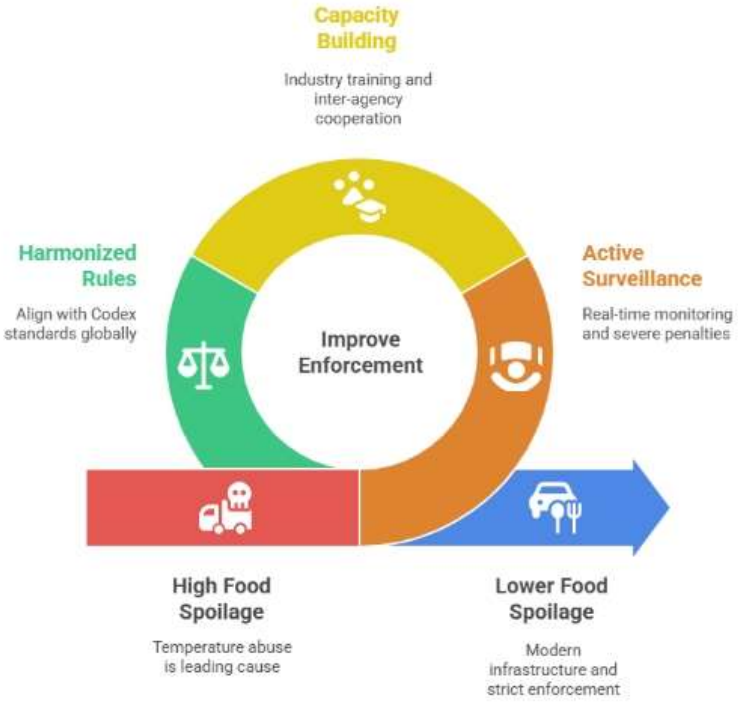

Conclusion:

India's approach to tackling the complex problem of food transportation and shelf-life preservation is increasingly distinguished by the integration of state-of-the-art technology and locally applicable innovation. The Indian cold chain industry, which expanded at a rate of more than INR 1,678 billion in 2023 and is predicted to grow more than double by 2028, demonstrates not only the rising demand for perishables but also a proactive effort to improve logistics and prevent post-harvest losses. Food safety and regulatory compliance are changing as a result of this modernization, which is backed by a number of preventive measures and legislative changes.

The usage of digital cold chain monitoring systems is one of the main tenets of this revolution. With IoT-based solutions tailored to India's infrastructure realities, such as the problem of limited internet connectivity in rural India, companies like ColdTrace and Emvantage Mobility have set the standard. With SMS-based alerts for variations that could jeopardize food safety, these systems provide real-time temperature and humidity monitoring across the supply chain. These technologies are now widely used, particularly in the transportation of high-value horticulture crops, dairy products, and pharmaceuticals, where even a brief loss of temperature control can result in significant spoiling or pose a risk to public health. Another significant advancement is blockchain-based traceability initiatives. Blockchain networks that track produce from farm to table have been tested by Indian exporters, especially in Kerala's spice trade and Maharashtra's grape sector. By creating permanent records of each transaction and freight transfer, these platforms facilitate the prompt identification of problem areas and the more precise assignment of blame for contamination or deterioration. Its legal and regulatory ramifications are extensive: blockchain data may be used as admissible evidence in consumer

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ISSN : 3049-3927(Online)

complaints and regulatory enforcement actions, improving supply chain accountability and transparency. The persistent issue of unstable power supplies in rural India is resolved by mobile cold storage devices such as Ecozen's solar-powered coolers. These technologies enable smallholder farmers to participate in high-value supply chains without being exposed to the danger of catastrophic loss due to spoiling by providing affordable, decentralized storage and transportation solutions. In addition to improving food security, this supports government initiatives like the Integrated Cold Chain and Value Addition Infrastructure Scheme and the Pradhan Mantri Kisan Sampada Yojana, which together have created over 38 million metric tons of storage space and plenty of jobs.

Notwithstanding these advancements, the cold chain sector continues to face regulatory and infrastructure shortcomings. Uneven loading and unloading locations, insufficient climate-controlled parking in transport hubs, and a lack of rural road connectivity cause mechanical damage and spoilage during transit. Furthermore, transporters and logistics firms are struggling to comply with the regulatory system, which remains in disarray due to interstate variations and redundant licensing requirements, particularly in the wake of the Agricultural Produce Market Committee (APMC) Acts.

A comparative review of current preventive measures and ongoing challenges is provided below:

PREVENTIVE MEASURE	INDIAN CONTEXT (2021–2025)	INTERNATIONAL BEST PRACTICE (EU/USA)
Digital Cold Chain Monitoring	IoT sensors in pilot zones; SMS alerts for rural areas; limited cloud integration	IoT-enabled systems with cloud-based analytics, real-time tracking, and universal coverage across regions
Blockchain Traceability	Pilots in select crops (e.g., basmati, organic); limited regulatory embedding	Broad adoption across agri-food chains; integrated with regulatory compliance and consumer transparency
Mobile Cold Storage	Solar-powered units for smallholders; NABARD/startup support; decentralized deployment	Grid-powered, large-scale units; centralized logistics; integrated with retail and export infrastructure
Infrastructure Development	PM Gati Shakti, Agri Infra Fund; urban-centric growth; rural gaps persist	Mature logistics networks; standardized cold chain protocols; seamless rural-urban connectivity

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ISSN : 3049-3927(Online)

Regulatory Coordination	Fragmented enforcement; overlaps with APMC and state food authorities	Centralized food safety authorities (e.g., FDA, EFSA); harmonized standards; single-window clearance
Training & Capacity Building	FSSAI's FoSTaC with regional language modules; voluntary participation	Mandatory certification; continuous professional development; digital learning platforms
Digital Licensing & Compliance	FoSCoS rollout; integration with GST/PAN; uneven adoption	Unified digital portals; automated compliance tracking; integration with customs and trade systems
Consumer Awareness Initiatives	Eat Right India campaign; school/workplace outreach; limited rural penetration	Nationwide nutrition labelling, public dashboards, and consumer advocacy groups are actively engaged
Food Testing Infrastructure	NABL-accredited labs expansion; mobile vans; gaps in tier-2/rural zones	Dense network of accredited labs; rapid testing protocols; AI-assisted diagnostics
Public-Private Partnerships	Collaborations with e-commerce/logistics firms; pilot-level hygiene standards	Institutionalised PPPs; co-regulation models; industry-led innovation in traceability and safety

Table No.3: Current Preventive Measures

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