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AN ANALYSIS OF FOOD PROCESSING TECHNOLOGY IN A SUSTAINABLE FOOD SUPPLY CHAIN IN THE COIMBATORE DISTRICT

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Abstract
In the food sector, supply chain management is essential since it involves coordinating and managing a range of activities from food supply to consumption. The manufacture of raw materials, packaging, distribution, and retail are only a few of the many steps that make up the complicated food supply chain. In India, the food processing industry plays a vital role in the country's economic development. To ensure inclusive growth, it is necessary to integrate this sector into the national strategy by creating a conducive environment that promotes investments in infrastructure, research, innovation, and technology advancement. Additionally, the government should incentivize the development of the food processing industry and raise awareness about the significance of processed foods. Sustainable practices in food manufacturing, including minimizing food waste, reducing energy consumption, and using eco-friendly packaging materials, are essential. Food processing not only enhances the edibility, taste, and safety of food but also enables its preservation beyond the harvest season. Moreover, it offers a wider range of food choices, thereby increasing consumer options. To maintain food safety, sustainability, and security, a comprehensive system is required on a global scale.

Key Words: Food technology, Supply chain, Processing Industry.

Introduction and the contextual of the study

Food processing plays a crucial role in our lives, encompassing a wide range of methods that yield diverse outcomes. Various techniques are employed to process and preserve food, such as canning, freezing, dehydration, pickling, and irradiation. The significance and extent of food processing cannot be overstated. Augustin et al (2016) stress the importance of keeping an eye on consumer attitudes and values to healthier comprehend the variables that could contribute to unfavourable opinions regarding food processing.

The most widely used method of food processing is likely cooking, which prepares food for consumption in various ways. Cooking can be carried out either at home or in a commercial setting, such as a restaurant or factory. According to Floros et al (2010), food processing plays a crucial role in the food production chain by connecting the agricultural provision of food to individuals in the required form and at the appropriate time. Food processing and preservation encompass all the activities and operations needed to convert raw agricultural produce into safe and nutritious food products to safe, healthy, and enjoyable food at affordable prices.

Food processing plays a crucial role in food by employing various methods such as controlling micro organisms, storing at low temperatures, dehydrating, and eliminating oxygen. Additionally, it brings about changes in the texture, flavor, and nutritional value of food products to cater to the preferences of consumers. Growth and people's dietary habits and lifestyles have undergone significant transformations; there has been a heightened awareness among consumers regarding food Ashley (2016).

Irani & Sharif (2016) Food security presents a wide range of difficulties that transcend national, social, institutional, and personal boundaries. Adopting enterprise actions to initiate and mitigate food security concerns is only possible through the identification of these elements.

Impact of Lazaridesa (2011) on food quality. WELS understood that maintaining a high level of product quality required careful consideration of both the freezing process and storage conditions, particularly water activity. Mahalik and Nambiar (2010) examine the fundamentals, obstacles, and tactics of supply chain management for businesses, focusing on the consequences for the Indian agri-food industry. The review conclusions show that innovation, teamwork, uncertainty removal, and the integration of global supply chain management practices into lean and green initiatives can address many aspects of sustainable agri-food supply chains, including human and environmental health, enhanced product visibility, food safety, and quality, and related economic benefits.

Costa et al (2013) framework to arrange the literature and enable a rapid content analysis that pinpoints future research directions as they assess the latest advancements in RFID technology in the agri-food industry. This industry appears to have a lot of potential with RFID technology; nevertheless, several obstacles are delaying its uptake.

Boye and Arcand (2013) offer industry-specific techniques to improve the adoption of environmentally friendly technologies in food processing and production. Sakthirama (2014) study was to map out the supply chain for organic food and to examine the consumer, two processors, and seven retailers/wholesalers who were chosen for the survey. Various pathways for organic food were identified, involving farmers, marketers, and consumers as members. It measured how various channel members felt about eating organic food. Additionally, the difficulties that supply chain participants confront were noted for their practical relevance. Katsikouli et al (2021) blockchain-based systems for managing a supply chain offer significant benefits, such as faster and more reliable traceability.

Derqui, Fayos & Fernandez (2016) addressing plate waste as well as making thrown food more visible present opportunities for food waste reduction. Mahalik, Kim (2016) embracing the concepts and practices more slowly, developed nations are the ones using IT in the food industry the most. Examines supply chain management, traceability, food processing and packaging, and the use of nanotechnology in these areas.

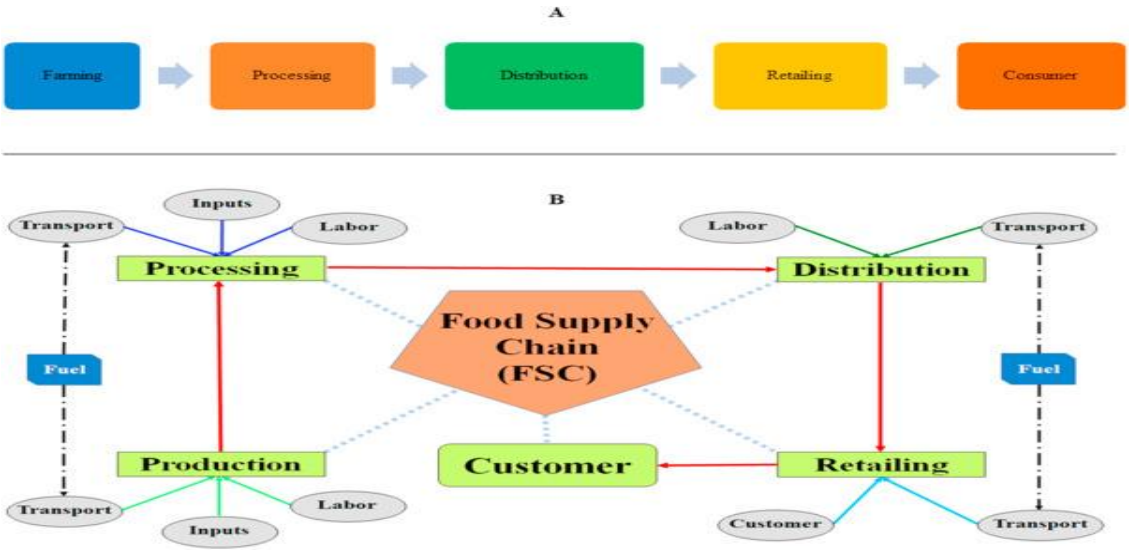
Mahajan et al (2017) relatively little empirical-prescriptive research has been done. As a result, the writers have offered a framework for classifying the literature related to FSCM. This will make it easier to do FSCM research in the future. The food business is substantially affected by Koufteros (2017) discussion of supply chain security since these traded goods pose serious risks to human life and the level of living. Concerns about food safety also pose a threat to the food supply systems.

Raak et al (2017) identified the following reasons why food is wasted in the processing industry: items that don't meet trade standards for quality and losses coming from processing operations and quality assurance.

Discover the ground-breaking research conducted by Sgarbossa & Russo (2017) as they strive to establish a revolutionary and sustainable model for CLSC. Their primary goal is to harness and repurpose waste generated from meat processing, paving the way for a greener future. By introducing key indicators such as profitability, energy self-sufficiency, and a qualitative assessment of social

implications, this study aims to evaluate the immense potential for global sustainability and the activation of new loops.

The paper by Khan & Ismail (2018) different obstacles and prospects linked to the Internet of Things in the agricultural industry. Among these, security emerges as a significant concern. To address this issue, it is crucial to bolster security measures through effective access control, data confidentiality, and user authentication.



(A) Activities in a simple food supply chain (FSC)
(B) Various components and sub-components in a food supply chain network.

Madumidha et al (2019) present a fully decentralized block chain-based traceability that enables building blocks for agriculture that continuously integrate with IoT devices from provider to consumer. The objective is to create a distributed ledger that is accessible by all users in the network which in turn brings transparency.

Zhao et al (2019) improvement of agri-food value chain management Scholz et al (2018) digital technologies in forest-based supply chains and summarize the state-of-the-art digital technologies for the real-time data collection on forests, product flows, and forest operations, as well as planning systems and other decision support systems in use by supply chain actors. According to Soysal (2015), the food business has recently faced difficulties in lowering food waste and increasing energy efficiency. Rahul et al (2018) food safety and security, high product quality, on-time delivery of products, and better order-fill rate.

Nurgazina et al (2021) implementation and measures Khouryieh (2021) purpose of this research was to observe food processing technologies implementing specific technologies, and the main drivers for innovation of non-thermal food processing technologies.

Astill et al (2019) enable technologies, provided by the Internet of Things (IoT), which can increase food production transparency. The IoT is the overarching technology that allows for data collection from multiple phases within supply chains leading to data-driven transparent systems of food production. Kamilaris et al (2019) challenges involve technical aspects, education, policies, and regulatory frameworks.

Mandal et al (2020) the food industry is trying to develop non-thermal processes for food preservation. Effects of PL on food quality, challenges of the process, and its prospects are presented. Lezoche et al (2020) organized within the use of such technologies, Haji et al (2020) were radio frequency identification, the Internet of Things, block chain, three-dimensional printing, autonomous vehicles, and unmanned aerial vehicles.

Chitrakar et al (2021) technological preparedness is worth discussing for the smooth running of food processing activities.

In the evaluation system for fresh food e-commerce logistics service quality, Jiang et al (2021) found that personal contact, timeliness, and empathy are key qualities that have a notable positive influence on consumer satisfaction. However, the study revealed that delivery quality and information quality do not hold significant importance in this regard. Additionally, the perceived importance of last-mile logistics services by consumers was found to have a significant and positive impact on their satisfaction with fresh food e-commerce logistics services.

Saurabh & Dey (2021) few potential drivers of block chain technology adoption, considering the grape wine supply chain and employing a rating-based conjoint analysis. The study finds that dis-intermediation, traceability, price, trust, compliance, and coordination and control in order of their relative importance and utilities can influence the supply chain actors' adoption-intention decision processes.

Alesiuniene et al (2021) results show IoT-connected sensors and systems in food and beverage supply chain logistics offer real-time visibility and data-driven analytics, allowing stakeholders to improve performance, cut operating costs, conduct predictive maintenance to avoid downtime, and even decrease energy usage or reduce negative environmental impacts.

Krishnaraj et al (2022) routes and the distance of traveling by spices in traditional and organized retailing from the agricultural location to the consumer Mehannaoui et al (2023) study focuses on future challenges in supply chain management (SCM), including issues relating to globalization, environment, and supply chain integration.

Mostaccio et al (2023) the fourth industrial revolution is revolutionizing food waste and contamination optimizing processes and saving money, and enhancing health conditions and safety in food consumption. Among them, radiofrequency identification has been considered from the beginning a key instrument, especially in food logistics and management.

Dadhaneeya et al (2023) Food manufacturing and processing industries need to accelerate and shift towards using technology like the "Internet of Things" (IoT) to meet demand, produce extremely safe food, and sustain the organization's goal.

Kumar et al (2023) Industrial Internet of Things is also an integrated component; the processing industry is compelled to adopt faced after adopting the new technology. Morchid et al (2023) n IoT and sensor technologies smart agriculture, including superior efficiency, expansion, reduced resources, cleaner method, agility, and product quality improvement. This study will contribute to helping future readers and researchers to comprehend the state of academic achievement in this subject.

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Objectives of The Study

I. To determine the importance and Benefits of the food processing Industry in supply chains.
II. To identify the various technologies and challenges of the food supply chain .

Research Methodology

The methodology used in the study points out the methods followed to realize the objectives of the study which include research design, sampling design, sources of data, collection of data, processing of data, period of coverage, and framework of analysis.

Research Design

The vast data have been composed from principal sources. Therefore, to present, describe, and interpret such mass data in the present research report, it is necessary to adopt the appropriate research design. The research design selected for the study is a descriptive one. The primary independent of the study is to examine food processing technology in a sustainable food supply chain.

Source of Data

The study is mainly focused on primary data which were collected through well-designed questionnaires to suit the points of this research. The principal data have been supplemented by secondary sources. The necessary secondary data relating to the study have been gathered from books, journals, websites, reports and journals, magazines, and newspapers.

Sample Design

Stratified random sampling was adopted to select the sample respondents.

Framework of Analysis

For analysis, statistical tools such as (i) Percentage Statistics (ii) Chi-Square (iii) Friedman Test

Analysis and Interpretation of Data

Table 1: Gender

Gender	Frequency	Percent
Male	79	52.7
Female	71	47.3

Table- 1. The results demonstrate that 52.7% of them are in the manly order, while,47.3% of them are in the womanish order.

Table 2: Age

Age	Frequency	Percent
18-29 Years	50	33.3
30-44 Years	35	23.3
45-59 Years	50	33.3
Above 60 Years	15	10.0

Specifies the age of the respondents, 33.3% of them are falling into 18 – 29 years, while, 23.3% of them are falling into 30-44 years, 33.3% of them are falling into 45-59 years and Above 60 years 10%.

Table 3: Qualification

Qualification	Frequency	Percent
Diploma	93	62.0
Bachelor Degree	31	20.7
Master Degree	26	17.3

Table 3 shows education qualifications are Diploma 62%, Bachelor Degree is 20.7%, Master Degree is 17.3%.

Table 4: Designation

Designation	Frequency	Percent
Student	28	18.7
Government Job	34	22.7
Private Job	22	14.7
Own Business	29	19.3
Retired / Unemployed	37	24.7

Table 4, designation of the respondents' Students is 18.7%, Government job 22.7%, Private Job is 14.7%, Own business is 19.3%, Retired/ Unemployed is 24.7%.

Table 5: Marital Status

Marital Status	Frequency	Percent
Single	79	52.7
Married	71	47.3

Table 5, Marital Status is Single repliers are 52.7% and married is 47.3%.

Table 6: Area of Residency

Area of Residency	Frequency	Percent
Rural	46	30.7
Urban	104	69.3

Table 6, Area of Residency, rural percent 30.7%, and the urban 104 (69.3%).

Table 7: Monthly Salary

Monthly Salary	Frequency	Percent
Less than Rs.10,000	33	22.0
Rs.10,001 - Rs.25,000	51	34.0
Rs.25,000 - Rs.50,000	22	14.7
Rs.50,001 – Rs.1,00,000	14	9.3
More than Rs.1,00,000	30	20.0

Table 7, Monthly salary is Less than 10 K is 22 percent, 10K - 25 K is 34%, 25K - 50K is 14.7%, 50K-1L is 9.3%, More than 1,00,000 is 20%,

Table 8: Wastes Produced

Wastes Produced	Frequency	Percent
Fruit and vegetable industry	30	20.0
Meat industry	50	33.3
Oil industry	31	20.7
Dairy industry	39	26.0

Table 8 indicates the Waste produced by various food industries Fruit and vegetable industry (30) 20%, the Meat industry (50) 33.3%, Oil industry (31) 20.7%, Dairy industry (39) 26%.

Table 9: Food Processing Waste

Food Processing Waste	Frequency	Percent
Poultry waste	22	14.7
Vegetable Wastes	30	20.0
Fruits waste	23	15.3
Mariline waste	21	14.0
Oil residue	20	13.3
Brewery waste	2	1.3
Bakery waste	10	6.7
Meat waste	22	14.7

The highest percentile of food waste is Vegetables is 20% and the lowest percentile of food waste is Brewery waste.

Table 10: Various Technologies

Various Technologies	Frequency	Percentage
Radiofrequency identification (RFID)	26	17.3
Internet of Things (IoT)	44	29.3
Block chain	13	8.7
Autonomous vehicles	16	10.7
Unmanned aerial vehicles (UAVs)	37	24.7
Three-dimensional printing (3DP)	14	9.3

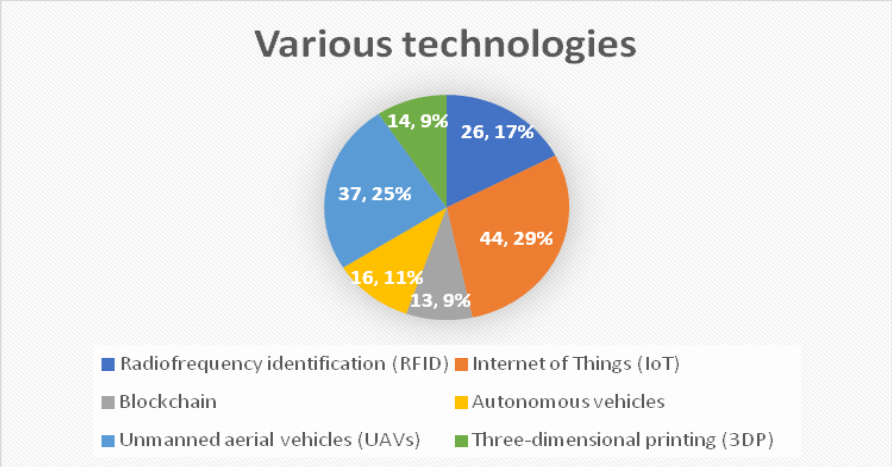

Figure 1: Various technologies in the food supply chain

Table 11: Challenges of the food supply chain

Variables	Chi-Square	DF	Asymp. Sig.
Storage Capacity	10.667[a]	1	0.000
Scalability	121.960[b]	2	0.000
Privacy Leakage	10.667[a]	1	0.001
High Cost	44.827[a]	1	0.000
Regulation Problems	15.360[a]	1	0.000
Latency Issues	259.560[b]	2	0.000
Lack of skills	121.960[b]	2	0.000
Lack of adequate infrastructure	10.667[a]	1	0.000
Shortage of skilled workforce	44.827[a]	1	0.000
High cost of energy	54.880[b]	2	0.000
Lack of proper storage facilities	113.880[b]	2	0.000
Poor market exposure	86.440[b]	2	0.000

The chi-square calculated value is in between the (10.667 to 259.560) all the sig values are less than the p-value of 0.05, then reject the null hypothesis.

Table 12: Benefits of Food Industry Supply Chains

Variables	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Improved negotiating positions for farmers	246	337	-0.931	0.352
Increased communication between producer and consumer	224.5	315.5	-1.299	0.194
Reduced transportation costs	225.5	316.5	-1.295	0.195
Increased transparency	246	337	-0.931	0.352
Increased quality	252	1242	-0.735	0.462
Greater profits	283.5	1273.5	-0.053	0.957

To perform the Mann-Whitney U test, our dependent variable (Benefits of Food Industry Supply Chains) into the Test Variable List box, and our grouping variable into the Grouping Variable box. The Mann-Whitney test works by converting scores into ranks while ignoring the grouping variable, and then comparing the mean rank of each group. If the difference between the mean ranks is big enough to be significant, then the null hypothesis that the samples derive from the same population is rejected.

Friedman Test

Table 13: Ranks - Importance of Food Processing

Importance of Food Processing	Mean Rank
Provides opportunities for import substitution	4.64
Enhance shelf life	2.88
Increase variety	3.18
Improves quality of food	3.16
Easing marketing and distribution tasks	3.23
Increasing food consistency	3.90

Test Statistics	
N	150
Chi-Square	184.292
DF	5
Asymp. Sig.	.000
a. Friedman Test	

The information in the table includes the test statistic ($\chi 2$) value, degrees of freedom (DF), and the significance level (Asymp. Sig.), which are all necessary to report the result of the Friedman test. The test shows a statistically significant difference in the mean ranks of the related groups. However, it is important to remember that the Friedman test, similar to its parametric alternative.

Recommendations and Conclusion

Fruit and vegetable waste and by-products are abundant sources of bioactive substances, possessing functional ingredients that exhibit antioxidant, antibacterial, and various other properties. Advanced technologies enable the utilization of these waste materials as ingredients, food bioactive compounds, and even biofuels Zhu et al (2023). One of the main issues facing Earth that has had a significant impact is food waste. Although solutions have been identified, the cost makes progress difficult. IoT has the potential to improve overall sustainability practices, reduce energy consumption, reduce manufacturing costs, enhance worker health and safety during food manufacturing, create eco-friendly products, and improve working conditions. Reducing bakery waste can be achieved through careful planning and scheduling of production, proper storage and handling of ingredients & products, and regular monitoring of inventory to ensure that products are. Reducing food loss and waste generates benefits for economies, for businesses and consumers, for human health, and the environment. To enhance the quality and nutritional value of food, the food industry focuses on raising crop yields while cutting waste, minimizing pesticide and fertilizer use, and promoting sustainable farming practices. Food technology plays a crucial role in ensuring the safety, quality, and nutrition of food. It offers various job opportunities such as engineers, scientists, operators, and quality inspectors. Additionally, food technology is involved in the expansion of new food products, food processing, and packaging.

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