



Harnessing AI and Big Data to Reduce Food Waste Across the Supply Chain: A Context-Specific Solution for India

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Research Question: To what extent can data and AI-driven technologies reduce food waste across the supply chain in India, and how can innovative solutions address the specific challenges of the Indian context?

Abstract

Food waste poses a critical global challenge, with developing nations like India experiencing unique barriers rooted in infrastructure gaps, limited technological access, and socio-economic disparities. This paper examines the potential of data and AI-driven technologies to mitigate food waste throughout the intricate food supply chain. The paper further acknowledges how, while global initiatives such as IBM's Watson and Too Good To Go highlight the transformative power of AI and IoT, these solutions often fail to directly address the structural and logistical hurdles within the Indian context. The paper accordingly proposes a tailored solution: a dual-component system comprising a remote crop monitoring device and an AI-powered logistics application. This model supports farmers in production, streamlines supply chain logistics, and ensures timely access to the market. The paper concludes by emphasizing the need for contextual innovation, awareness, and government support to realize the full potential of AI in combating food waste in India.

Key Words: food waste, AI in agriculture, Big Data, India supply chain, technological innovation

Introduction

The world squanders the very resources that its people need..

Food waste is a global crisis. According to the Food Waste Index Report authored by UNEP and WRAP (2024), one-fifth of all food produced for human consumption is lost or wasted globally. To put this into perspective, this amounts to 1 billion meals every day. Food loss and waste account for up to 10% of global greenhouse gas emissions,

equivalent to almost 5 times the total emissions of the aviation industry. The implications of food waste on developing nations like India are critical to their growth. India is home to over 1.43 billion people, out of which more than 230 million people go to bed hungry at night, according to the Global Hunger Index 2023 report (Choubey, 2024). India has been ranked far behind other countries, depicting a hunger severity level of ‘serious’ for the country. Despite having such a large food-insecure population, the amount of food wasted per person has remained high. It is estimated that the value of food wastage in India is around ₹92,000 Cr (Arora, 2023). This staggering figure underscores the urgent need to minimize waste throughout the various levels of the food supply chain.

Big data and artificial intelligence have helped solve countless problems on Earth. Industry 4.0 and its technologies can pave the way for efficient, smart, and sustainable solutions to address the problem of food waste and loss. These technologies are poised to enhance food quality and safety, promote environmental sustainability, and improve operational efficiency throughout all stages of the food supply chain (Onyeaka et al., 2025). However, these solutions may not fit all countries and cannot be generalized. Each country is unique, and these technologies must be tailored to a country’s specific needs and demands. Considering the aforementioned, this research paper aims to answer the following question: **To what extent can data and AI-driven technologies reduce food waste across the supply chain in India, and how can innovative solutions address the specific challenges of the Indian context?**

This research paper argues that AI and new emerging technologies hold immense potential, but addressing the problem of food waste in India requires domain-specific and resource-feasible solutions that integrate technological innovation and practical implementation strategies.

Background

The food supply chain encompasses the entire journey that food takes from farms to households. The chain consists of various factors at different tiers, all of which are responsible for transforming raw materials from farms, commodities, and various items into finished products (Oyedijo et al., 2024). The various stages of this chain are commonly recognized as: production, post-harvest, processing, distribution, and consumption. Food loss or waste occurs on each level due to multiple varying reasons.

Food loss is “the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption” (Breewood, 2019), including the production, postharvest, and processing stages. It can also be termed as the unintentional reduction in the food quantity or quality during production, post-harvest, and processing stages, which often occurs due to poor infrastructure or supply chain inefficiencies. On the other hand, food waste is food loss that occurs at the end of the food chain, primarily during retail or final consumption. This food waste occurs due to behavioral or logistical issues, such as overstocking or improper storage.

An analysis of the specific reasons for food loss or waste at each stage of the food supply chain is below:

Production

The first stage of the food supply chain is production. It is the largest source of food waste, accounting for over 500 million tonnes annually (The World Counts, 2025). The primary reasons for losses are crop pests, ineffective harvesting, and irrigation. To safeguard themselves against adverse weather conditions, farmers often plant crops in excess of what is required for production. Furthermore, food production may not occur at all due to adverse weather conditions, pests, and crop diseases. Another practice, dumping, involves farmers not harvesting their crops properly due to unfavorable market prices and decreased consumer demand, thereby contributing to increased food wastage.

Post Harvest

Post-harvest losses refer to the losses that occur immediately after harvest. Food is lost on farms because of a variety of issues. For instance, insufficient drying of grains may lead to losses due to the development of moulds and insects. Threshing can cause losses due to broken grains and encourage the development of insects. Inoptimal storage conditions result in premature produce ahead of distribution. Moreover, even transport conditions or defective packaging of grain can lead to quantitative losses of product (PostHarvest, 2021). It is estimated that the postharvest and storage stage alone contributes to over 350 million tons of food loss (The World Counts, 2025).

Processing

Processing losses refer to the reduction in the quantity and quality of food that occurs during processing steps such as washing, cleaning, gutting, chopping, and drying (Murphy, 2024). Food may also be lost during the grading process, which comprises selecting and classifying food products based on their physical appearance and quality (Kiaya, 2014).

Transportation and Distribution:

Transportation is one of the most key parts of the food supply chain, as this is the part where the product reaches consumers and retailers. Perishable food products are often subject to food loss and waste because of improper storage and limited shelf life. The rejection of food shipments also leads to significant food waste in logistics during the transportation cycle. These products are then discarded if a suitable buyer is not found within a reasonable timeframe. It is estimated that between 2% and 5% of food shipments are rejected by food buyers (PostHarvest, 2021).

Consumption

The last stage of the food supply chain is consumption. Foods that are purchased and have been cooked but not consumed contribute to food waste at this stage. This stage alone is responsible for approximately 350 million tonnes of food waste globally each year, a figure that has been rising consecutively (The World Counts, 2025). Some of the most critical factors leading to food waste are behavioral issues - overpreparing, overbuying, and poor planning. Households account for the majority of food waste at the consumer and retail levels. The global household food waste produced in select countries, as of 2024, is illustrated in Image 1.



Problem Statement

Food waste is a global challenge, present in all types of countries. However, the challenges exhibit differently depending on the socio-economic and infrastructural contexts of various countries. Developed countries face the crisis more on the consumption side. In countries such as the United States, for example, the consumption level accounts for over 50% of total food waste. On the other hand, in developing countries like India, a lack of infrastructure, technological resources, and food storage facilities primarily leads to food waste. As part of this, a significant portion of the food is wasted before it reaches the consumer (Tarbox, 2020).

Focusing specifically on India, it is a country that relies heavily on agriculture. Over 55% of India's population depends on agriculture for their livelihood (IBEF, 2019). Contributing 14% to India's GDP, agriculture and food production are vital to the Indian economy and its development. Although this sector is crucial, food wastage remains a prominent issue in India. To put this into perspective, the FSSAI reported that 1/3rd of all food produced in India gets wasted or spoiled before it's even eaten, which amounts to approximately 90,000 crore INR (Arora, 2023; Times of Agriculture, 2023).

Several contributing factors to food waste and loss in India include inadequate infrastructure, a lack of cold storage solutions, limited storage capacity, low awareness, and slow technological adoption. To begin with, a significant portion of the food waste in India occurs immediately after the harvest season, when many crops and grains require adequate infrastructure for proper food storage. Unfortunately, many warehouses still lack this necessary infrastructure. They continue to be short of temperature-controlled facilities, adequate ventilation, and proper insulation. As a result, 30% of vegetables and fruits are lost before reaching markets and consumers (Lakhani, 2023). Ultimately, this food waste becomes a liability and a financial burden to the farmer, directly impacting their daily lives.

Apart from warehouses, cold storage facilities, which are crucial for storing perishable goods and products, are often unavailable or in short supply in rural areas, ultimately leading to many regions experiencing irregular food supplies. A more recent factor affecting the food supply chain in India is the slow adoption of technology. Even today, the food supply chain in India remains heavily outdated, relying on conventional methods of transport and storage. Moreover, India suffers from a lack of awareness. A vast majority of the Indian population believes that it is 'okay' to waste food and does not realize the severe implications of this action on the economy and the environment. A lot of food is prepared on occasions like weddings and community events, and, according to research, approximately 40% of the food prepared goes to waste or is simply discarded (Times of Agriculture, 2023).

As a country that relies heavily on agriculture and food production, the socio-economic burdens of food waste are vast. According to the Global Hunger Index, approximately 190 million people in India go hungry every night. When food is wasted, it not only doesn't reach those who need it, but the resources used in its production are also lost. Apart from the socio-economic burden, the environmental impact of food waste is also severe. When food reaches landfills, its decomposition releases methane, a greenhouse gas that contributes to global warming. Moreover, agriculture accounts for approximately 70% of the water used worldwide (Lewis, 2022). Therefore, when food is wasted, this freshwater is also wasted - a pressing issue for a country like India, where many of its cities are starting to struggle with water scarcity.

General solutions are insufficient to address India's food waste problems. A deep and detailed understanding of India's food waste landscape is vital in designing effective models and interventions. Being an agriculture-dependent economy, these breakthroughs and developments are crucial to India's growth.

Potential of Big Data and AI in Tackling Food Waste

Big data refers to vast, complex datasets that traditional data management systems cannot handle. When analyzed and managed correctly, big data can provide actionable insights and improve decision-making. Artificial Intelligence

(AI) is a technology that enables computers and machines to simulate human decision-making processes. The advent of AI has enabled organizations to make sense of their datasets, identify patterns, and optimize decisions, with the help of machine learning and predictive algorithms. So, AI and Big Data share a symbiotic relationship; with the ever-increasing number of digital interactions and processes, AI plays a critical role in leveraging advanced analytical capabilities for data analysis, while AI itself requires huge amounts of data for learning and improvement.

In the context of the food supply chain, AI and new-age technologies hold huge potential for drastically reducing food loss and waste by upgrading the entire end-to-end process.

Production

During the production stage, AI-powered devices and predictive analytics can forecast crop yields, weather conditions, and detect nutrient levels in the soil, as well as identify pests and diseases. For example, AI-enabled drones can observe and track physical changes to better understand crop needs, ultimately helping farmers produce higher yields. Machine learning algorithms can also accurately plan a farmer's crop requirements, resulting in higher yields.

Additionally, AI-powered technologies can assist in the production process and help reduce food waste caused by diseases and unpredictable weather conditions.

Post-Harvest

Moving forward, once a good crop is produced, factors such as storage, logistics, and distribution come into play. In storing crops in granaries and warehouses, AI-powered IoT devices can monitor storage conditions to ensure optimal temperatures and humidity. Furthermore, these devices hold the potential to prevent premature spoilage.

Distribution

At this stage, AI can help improve routes and travel for food transportation, ensuring minimal spoilage and reduced transport time. AI algorithms can process real-time data, such as traffic, time, and travel routes, to come up with more effective logistics. When implemented on a larger scale, such adoptions can increase shelf life, reduce wastage, and further make food more accessible to the public. Additionally, AI-image detection can analyse fruits and vegetables regularly to check for spoilage or contamination.

Consumption

Finally, at the consumption stage, AI-enabled platforms can help consumers, restaurants, and retailers manage inventory through demand prediction and adequately manage food stocks. This can lead to businesses not buying more than they need, which directly prevents food wastage. Moreover, AI can help build platforms for connecting surplus food to food-insecure communities, ensuring that all food reaches those in need. With improved data analysis

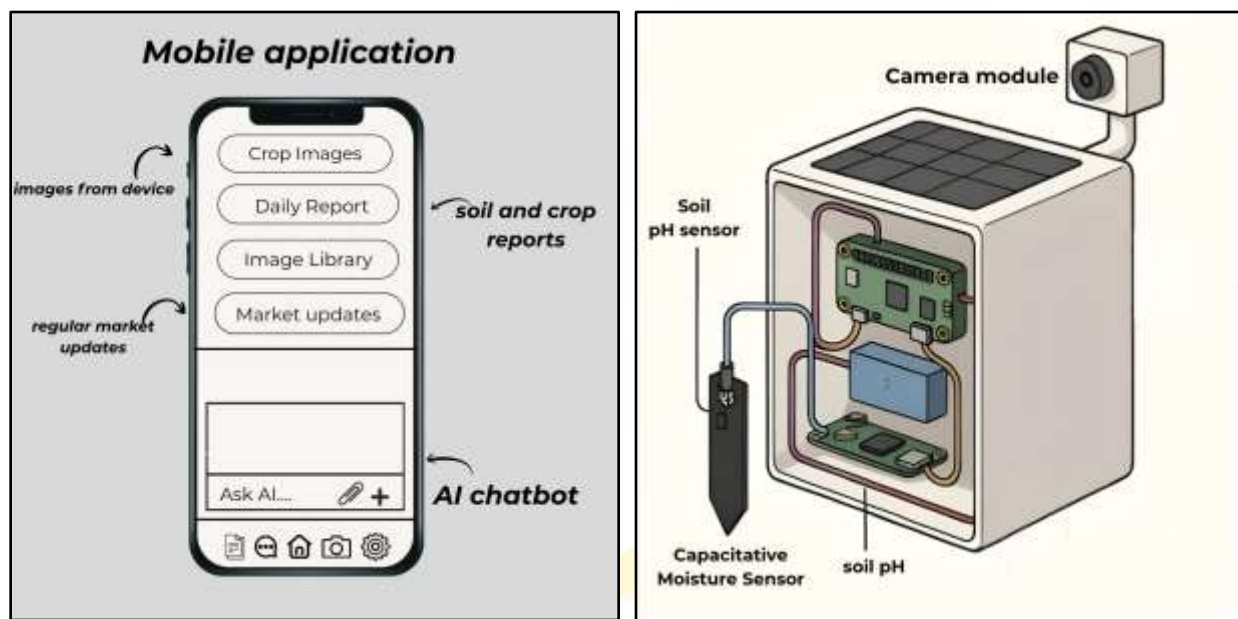
and algorithms, connectivity between businesses, restaurants, households, and food-insecure communities can become significantly more streamlined and efficient.

Globally, many corporations and start-ups are leveraging AI to tackle food waste and loss across the supply chain. A notable example is IBM's Watson Decision Platform for Agriculture, which was developed to help farmers and agribusinesses make more informed, data-driven decisions. By integrating IBM's advanced AI, IoT, and machine learning capabilities, the platform offers end-to-end solutions tailored to the complexities of agriculture, a sector marked by seasonal variability and environmental risk. Watson AI supports farmers in managing both pre-season planning and in-season adjustments, thereby reducing uncertainty and improving productivity. It also enables food companies to source higher-quality produce by enhancing traceability and supplier reliability. At the core of the platform is the Electronic Field Record, a tool that allows seamless data collection and monitoring, forming the backbone of its AI and IoT integrations. The platform serves a diverse range of stakeholders, including growers, agronomists, traders, and policymakers. Deployed in diverse contexts, IBM's solution has enhanced efficiency and transparency across the global food supply chain (Gildersleeve, 2025).

Another example of a company playing a pivotal role in reducing food waste is Too Good To Go, which leverages technology to redistribute excess food left at restaurants and hotels, providing it back to consumers at a lower rate. With the help of modern technology, Too Good To Go has saved over 400 million meals from being wasted (Too Good to Go, 2024). According to its annual report, Too Good To Go saved approximately 2.7kgs of CO2 emissions per meal saved on its platform, which proves to be monumental in fighting climate change globally. Moreover, many businesses have unlocked an additional source of income from Too Good To Go food dispatches, which have further increased popularity amongst consumers in preferring the companies' surprise bags.

Innovative Solution for the Indian Context

Big data and AI offer a range of potential solutions to the global problem of food waste. However, as previously discussed, their effectiveness in India hinges on a nuanced understanding of the specific factors that drive and exacerbate food waste within the country. In light of this, the researcher proposes a targeted solution: the development of an AI-powered application and complementary device designed to monitor the agricultural cycle. Together, they would deliver detailed insights into optimal planning and harvesting, supplemented by real-time market analysis and an integrated AI chatbot to assist farmers with timely guidance and decision-making support.



The solution consists of two main components: a portable device and an application (both pictured above). The portable device will be responsible for collecting data regarding crop health, soil conditions, and weather conditions, and transmitting it. It will feature a camera that actively scans crops and captures images, as well as soil pH sensors and moisture sensors to understand soil conditions. The device can rely on solar panels or batteries for all its electricity requirements. Components like IoT devices can be added to monitor crop storage conditions around the clock and alert farmers to potential risks of spoilage. These devices can work in conjunction with the mobile application, ensuring comprehensive security throughout the production and post-harvest seasons.

With data collection automated, the solution leverages India's internet connectivity and smartphone penetration to provide precise and tailored insights to farmers. To transmit data seamlessly, the device and application will be connected to the internet, benefiting all farmers who struggle with technology. The hyperlocal transmitted data will then be used to fine-tune an AI model, which will provide suggestions, structured insights, and detailed reports on the production cycle, thereby increasing productivity and reducing food loss. The AI model will feature multilingual inputs and advanced image recognition, enabling farmers to upload pictures and send audio messages to the model. This is vital, as India is a country where over 120 languages and 19,500 dialects are spoken (Owen-Hill, 2022). Overall, through interactions between farmers and AI bots, farmers can gain a deeper understanding of their crops, and the AI model can acquire a more comprehensive understanding of the farmers' needs and concerns. Apart from crop development and updates, the mobile application will also feature regular market updates, including crop prices, demand, and policy changes. Alongside this, the application will also provide connections to wholesalers and retailers in the vicinity of the farmer. This increasing online connectivity will empower farmers from remote rural areas, enabling them to engage in the market from the comfort of their own homes.

This solution can work with and for the farmer at every stage, resulting in higher crop yields and reduced crop losses. This would benefit all stakeholders, including the farmers themselves, as well as the consumers and the nation's food security.

Conclusion

Food waste is a global crisis that affects the world, contributing to environmental degradation, a significant financial burden, and the loss of valuable resources. However, differences remain in the reasons for food loss and waste, as well as how these adversities manifest, among developed and developing nations. To combat food loss, AI and Big Data can prove vital across all domains, with IoT devices, AI-powered applications, and machine learning algorithms being leveraged across all stages of the food supply chain. Many corporations have successfully initiated such integrations, such as surplus food start-up Too Good To Go and IBM's Watson Program.

As a developing country, India faces unique challenges, including limited awareness, slow technological adoption, and high poverty rates. Current solutions built around AI and Big Data are not sufficient and do not address core Indian challenges, meaning these solutions are more 'general' and do not cater to India specifically. Thus, to combat food loss and waste, a solution must be proposed that thoroughly identifies all factors and resources and tackles the issues in a structured manner. This research paper, in line with this, proposes a solution encompassing both a remote crop monitoring device and an AI application, which together work to improve the food production process. Furthermore, the AI application enhances logistics and helps farmers ensure that their produce reaches wholesalers on time.

With effective awareness and government intervention, this solution can have a profound impact on the food supply chain

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