Technological Innovations in Food Waste Reduction: Case Studies from East and Southeast Asia

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ABSTRACT

This study presents a review on food waste in East and Southeast Asia. Specifically, it highlights some of the key technological innovations being implemented in East and Southeast Asia to reduce the food waste. This paper contributed additional knowledge on the factors that contribute to food waste and the use of technological innovations to reduce food waste in East and Southeast Asia. A literature search was done on technological innovations being used in food waste reduction and several case studies have highlighted successful implementation of these technological innovations in Asia, encompassing the years 2018 to 2024. Based on the review, it is noted that the key features of technologies and practices of the food waste management as well as the cooperation between government and private sectors are important. The limitation of this study is that this study is only focusing on a few Asian countries. Therefore, this paper suggests that in future, researchers can focus on other countries as well as other regions. The identification of these innovations may highlight the importance of technology in reducing food waste, thus motivating other researchers, government, and private sectors to study technological innovations in food waste reduction more intensively.

Keywords: Technological innovation, food waste

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has highlighted the urgent need to enhance food security, and ultimately reduce food waste. Food waste includes organic wastes originating in food processing plants, thrown-out leftovers, expired ingredients, and unsold products, which is wasted at the retail and consumer levels (Joshi and Visvanathan, 2019; Kusuma, 2023). According to the United Nations Environment Programme's (UNEP) Food Waste Index Report, almost one-third of global food production were wasted by households, retailers, restaurants, and other food services in 2022 (UNEP, 2024). This equates to 1.05 billion tons annually, which leads to nearly a trillion United States (US) dollars in economic losses per year (Wood, 2023). Hegnsholt, Unnikrishnan, Pollmann-Larsen, Askelsdottir and Gerard (2018) highlighted that the amount of food wasted each year will increase to 2.1 billion tons by 2030, which is equivalent to 66 tons per second. The Food and Agriculture Organization (FAO) of the United Nations expected that global population will grow to 9.7 billion by 2050, and food demand is projected to increase by 50 percent to 70 percent (FAO, 2020). Thus, it is imperative to prevent and combat food waste. In addition, food waste is a vital issue, representing a social distress, an economic malfunction and an environmental disaster (Martin-Rios, Hofmann and Mackenzie 2021).

Although food waste is a worldwide problem, it is particularly alarming and pressing in Asian countries, in which hundreds of millions of people are living in hunger (Thiagarajan, 2024). It has been projected that Asia's major cities alone will produce around 1.8 billion tons of food waste by 2025 (Agamuthu and Babel, 2023). The International Council for Local Environmental Initiatives (ICLEI) highlighted that East Asian countries experience considerable challenges in managing and reducing food waste, and are striving to tackle this issue (ICLEI, 2019). Alarmingly, three East Asian countries, namely China, Japan and South Korea, made up nearly 30 percent of the world's wasted food (Lu, 2023). In Hong Kong alone, 3,500 tons of food waste were generated daily, which accounts for 35 percent of the municipal solid waste, while 50 percent of them are recyclable. Since there is no legislation requirement for food waste separation for collection and recycling, disposing food waste at landfills is a common practice, which negatively affect environment, leading to pollution and climate change.

In addition, food waste also includes waste of resources used in its production, harvesting, transportation, and packaging. Hence, immediate attention is required as it contributes towards the monetary losses of both individuals and national economies (Heidari, Mirzaii, Rahnama and Alidoost 2019).

Meanwhile, Taiwan generates nearly 16.5 million tons of food waste each year, which is enough to feed millions of people (Heberlein, 2018). In 2022, approximately 1.327 kilograms (kg) municipal waste per person per day were generated, in which around 20 percent was organic waste which consists of food waste and garden trimmings (Singh, 2023). Although Taiwan was once known as "Garbage Island", this country has significantly improved with a world-beating recycling rate of 55percent. Taiwan is also slowly becoming a global leader in solid waste recycling (Rapid Transition Alliance, 2019), although the country still struggles in battling food waste problems. Food waste costs Taiwan taxpayers billions of dollars a year, and it became the most significant source of air and water pollution (Heberlein, 2018). In Mongolia, about 2.9 million tons of solid waste is generated annually, for which most of them is not recycled. Solid waste in this country is disposed either in formal landfills or illegally dumped elsewhere (Brooks, 2022). Majority of the solid waste are food waste that comes from unserved food, leftover food, and unavoidable trimmings and peelings during preparation of the food, which has room for improvement. For many Asian countries, managing organic waste is a major challenge although it is biodegradable. Despite disease transmission risks, organic waste emits methane during decomposition, a gas that greatly contributes to global warming.

Similarly, food waste is a major concern in Southeast Asia. The region accounts for 25 percent of global food waste, which is around 50 million metric tons of food each year (Food Cycle Science, 2023; Food Market Hub, 2023). Five most significant contributors of food waste in Southeast Asia includes Indonesia (20.94 million tons/year), the Philippines (9.33 million tons/year), Vietnam (7.35 million tons/year), Thailand (5.48 million tons/year), and Myanmar (4.67 million tons/year). Listed just after Myanmar, Malaysia produces 2.92 million tons of food waste each year (UNEP, 2021). Solid Waste Management and Public Cleansing Corporation (SWCorp) reported that Malaysia produces 17,000 tons of food waste daily, in which 24 percent was still edible. This is equivalent to 4,080 tons of good food going to waste every day (The Star, 2024). In the UNEP report 2021, Singapore was listed far away from its neighbouring countries, with only 0.47 million tons of food waste per year. However, TTG Asia Media reported that Singapore generates around 1.6 billion tons of food waste every year, which is worth 1.2 trillion US Dollar (Lee, 2023). One of the largest generators of food waste in Singapore are buffet lines in the hospitality industry. Although hotels are making commitments to reduce food waste, some are just unavoidable. Besides that, the impact of food waste reduction is much more prevalent in larger hotels with greater food chain.

It is important to note that food waste is particularly prevalent in Southeast Asia due to its supply chain and food system infrastructure. Overall, in Southeast Asia, 30 percent of food is lost during production, and 35 percent is lost during post-harvest handling and storage (Agamuthu and Babel, 2023). Although food waste is still considerable in the urban areas, rural areas suffer a majority of losses at the earlier chain before reaching supermarkets or consumers, which is commonly referred as "food loss". Food loss accounts for the losses that occurs in the post-harvest level, including processing, storage, packaging, transportation, marketing, and retail (Kusuma, 2023). Post-harvest loss can either be qualitative and quantitative loss. Qualitative losses include those affecting nutrient composition, viability or visual and aesthetic appeal, contamination, and breakage; while quantitative losses occur when the amount of the food reduces over time (World Economic Forum, 2023). Improper infrastructure for food storage and transportation is a significant contributor to food loss in Southeast Asia. For instance, around 20 percent of cereal grain is lost in Thailand, with the largest loss occurred during processing and storage. Meanwhile in the Philippines, about 33 percent of loss was incurred at the drying process of rice (Kusuma, 2023).

The United Nation Sustainable Development Goal 12, target 12.3 (SDG 12.3) aims to halve per capita global food waste at both retail and consumers levels, and to reduce food loss across supply chain by 2030. However, according to the Global Hunger Index (GHI) 2018 report, 50 countries will fail to achieve the United Nation's SDG of zero hunger by 2030 without any intervention due to food insecurity, climate change, poor governance (The ASEAN Post, 2019). A small number of countries are demonstrating progress in supporting such effort. In the East Asian region, Japan shows a significant reduction of 31 percent on food waste as compared to 2021, as the issue has been tracked consistently in the recent years (UNEP, 2024). In China, law on food waste has been

adopted in 2021 with an aim of fostering food waste prevention. Therefore, companies should respond to disclosure requirements regarding waste management (Martin-Rios, Rogenhofer, and Alvarado 2023). As the issue of food waste involved all parties in the food chain, collaborative action amongst these parties are essentials for its success.

Fortunately, the collaborative action is possible with the use of technology, that make changes plausible, easier, and faster (Birch, 2022). Technology and innovation are arguably one of the most important elements that encourage changes and improvements in food waste management. The emergence of innovative technological solutions offers promising strategies to combat food waste in the region. Despite improving business performance, adopting digital technologies and innovations in the food supply chains demonstrate significant efforts to overcome challenges in reducing food waste (Annosi, Brunetta, Bimbo, and Kostoula 2021). This article reviews some of the key technological innovations being implemented in East Asia and Southeast Asia, including smart inventory management systems, food sharing apps, and waste-to-energy technologies.

LITERATURE REVIEW

Types of Technological Innovations in Food Waste Reduction

Several types of technological innovations have been introduced to reduce food waste in Asia, and this paper reviews the technologies that have been studied. It is suggested that Smart Inventory Management Systems, Food Sharing Apps, and Waste-to-Energy Technologies are among the innovations that have effectively reduced food waste in Asian countries. The following sections discuss how these technological innovations contribute to reducing food waste..

Smart Inventory Management Systems

One of the critical technological advancements in reducing food waste is the development and implementation of smart inventory management systems. These systems utilise artificial intelligence (AI) and machine learning algorithms to optimise the inventory levels of food retailers and suppliers. By using AI in the inventory management system, business may reduce the risk of spoilage and wastage with real-time data analysis, such as demand forecasting, to help them make informed decisions about purchasing, storage, and shelf-life management to avoid overproduction. In Japan, for instance, several supermarkets have adopted AI-driven systems that predict demand more accurately, ensuring that fresh produce is stocked in appropriate quantities and reducing the likelihood of overstocking and subsequent waste. These systems do not only help in minimising food waste, but also enhance operational efficiency and profitability for businesses (Minai and Obayashi, 2019).

In Thailand, AI-powered system developed by Smartway is used by stores in Bangkok and its surrounding areas to address food waste issue. This technology uses AI to identify products that reaching its expiration dates, apply 20 percent to 40 percent discounts, and enhance ordering process to minimise waste. Besides reducing food waste, the system helps to boost customer purchasing power and improve store efficiency. The key features of the Smartway's digitalised food waste management solutions include automatic detection through "GPS Short Date" system that identifies nearing-expiration products, optimal recycling that determines the most profitable recycling channel, automated discounts with distinct labels for nearing-expiration products, and improved ordering procedures for precision and waste minimisation (Retail Asia, 2024).

Food Sharing Apps

Food sharing apps have gained significant traction in Asia as an effective means to redistribute surplus food and reduce waste. These apps connect individuals and businesses with excess food to those in need, ensuring that edible food is not discarded. In South Korea, the app "No Food Waste" has become popular, enabling users to share information about surplus food available in their vicinity. In Japan, "Tabete" app, which was released in 2018, is a free app that has helped to save 384,000 meals, accumulated 525,000 users, and partnered with 2,140 shops (The Straits Times, 2022). This app also provides information to educate users with tips on reducing food waste, and recipes on their social media pages to promote food sustainability. Another app called "EcoBuy" provides awards in the form of reward points to consumers who use the app to buy items that are coming to the

end of its shelf-life, with the aim of reducing food waste. There are about 30 designated food items in the app, including bread, sashimi, and milk (Wan, 2018). The app also provides latest information about the food items included, alert users of the best-before dates, consume-by dates, and recipes for food they purchased. Similarly in China, the "Meituan" app includes features that allow restaurants and consumers to share surplus meals at discounted prices. These platforms promote a community-centric approach to food waste reduction and support social initiatives aimed at alleviating hunger. All these apps enable suppliers to provide food banks that distribute unsold food to the needy families (Minai and Obayashi, 2019).

In Southeast Asia, many start-ups have begun attempting to bridge the gap between food waste and hunger, making it easily accessible for those in need. For instance, “UglyFood” in Singapore redistributes ‘ugly’ produce food such as fruits and vegetables, that would otherwise been disposed of by retailers. The food that is considered ugly and not cosmetically attractive is wasted more compared to perfectly looking fruits and vegetables, as it is less likely to be sold by the stores or to be purchased by the consumers. Another app known as “Too Good to Go” connects food and beverages (F&B) outlets with consumers in order to redistribute excess and unsold food at the end of each day at a discounted price (Birch, 2022). The app is also being used in Thailand.

In Malaysia, a Grub Cycle app known as “Grub Bites” was founded in 2016, allowing registered users to buy food from selection of listed restaurants at discounted prices. This initiative enables restaurants, cafes, and bakeries to sell off the over-produced food at bargained prices, while at the same time still able to make revenue, and more importantly help to reduce food wastage. The co-founder of the app, Redza Shahid, highlighted that 2.2 million people can be fed with three meals a day from the food that the country generates (Ladrido, 2017). This increases the urge for the Grub Cycle team to grow with “Grub Groceries”, “Grub Homemade”, and “Grub Bag”. The “Grub Groceries” provides a platform for redistribution of rejected or surplus supermarket products at a discounted price, which is commonly around 20 percent below retail price. Meanwhile, the “Grub Homemade” offers pickled vegetables and fruits jams that are re-engineered by the company’s chef to extend the lifespan of a product. With “Grub Bag”, the company solely intent to assist low-income communities by providing necessities including rice, cooking oil, sugar, salt, and eggs, at only 50 percent of the retail price. In order to sustain the business with proper mechanisms, 10 percent of profits gained from the other three programs would be channed to help support this initiative.

Waste-to-Energy Technologies

Asian countries have also made strides in utilising waste-to-energy technologies to address food waste. These technologies convert organic waste into renewable energy, providing a sustainable solution to waste management. The most common option for managing food waste using this method in Asian countries is anaerobic digestion technology (Joshi and Visvanathan, 2019). It is widely recognised as more energy-efficient and environmental-friendly method of treating food waste (Zaini, Mohd Yatim, Dasiman, Abdullah and Mohd Zainuddin 2023).

In Taiwan, 75 percent of its food waste would undergo underwater treatment to make pig feed. However, this approach is expensive and inadequate to solve high daily volume of organic waste. Although the country has long struggled to solve its food waste issue, the government has invested in anaerobic digestion facilities that processes food waste and produce biogas, which is then used to generate electricity. Additionally, Taiwan fights for its organic waste by addressing processing technologies through enterprises. Taiwan also uses "state-of-the-art" target enzyme technology to treat organic waste to produce high quality organic fertiliser. The innovative technology transforms waste into soil-enriching fertilisers within three hours instead of two to four months for traditional composting. Due to its quick processing time, the overall emissions using this technological innovation are less than 100 kilograms (kg) of carbon dioxide of organic waste, as compared to 450 kg for traditional composting and 750 kg for landfills (Singh, 2023).

In China, black soldier fly larvae (BSFL) technology is used as bioconversion of organic wastes into value-added larval biomass products, such as nutrient-rich feed and organic fertiliser (Salam et al., 2023). This technique is a way of conversing terrestrial waste into biogas, biofuels, and other valuable converted products, which can be used in the agricultural field. Consistently, the same approach is also used in Taiwan, and being recognised as the best solution to organic waste problem in terms of reducing its carbon footprint (Singh, 2023). In Southeast

Asia, Singapore is one of the countries that adopted this method, whereby the residents can contribute their food waste to established black soldier fly facility, where the larvae act as a decomposer and break down the food waste into frass, which can be used as an organic fertiliser (TUM Asia, 2023).

Consistently in Southeast Asia, waste-to-energy plants, which help to convert non-recyclable waste into energy using combustion to generate electricity are being constructed in Singapore, Thailand and Indonesia (Carruthers, 2024). In Singapore, the National Environment Agency has implemented pilot projects that convert food waste into bioenergy and compost. These initiatives do not only reduce the volume of food waste sent to landfills, but also contribute to the generation of clean energy. In addition, better recycling practices are being encouraged in Singapore via the usage of "smart wastebins" or "smart bins", which utilise increasingly sophisticated technologies such as AI and Internet of Things (IoT) (Carruthers, 2024). The bin uses variety of sensors and computer vision to identify items that are about to be thrown away and track the amount of food wasted. The food waste is later turned into energy or fish feed. However, based on the results of a recent poll conducted by Singaporean research company, Blackbox, only 5 percent of the participants confirmed that they recycled food. This indicates that there is sharp disparity between the scope of food waste problem and the level of commitment and involvement displayed by the public in addressing the issue (Diinsider Life, 2024).

In Malaysia, MAEKO's food waste composter, which uses a specially formulated composting enzyme to convert all types of organic waste into compost, are being placed in practice. This includes garden waste, raw kitchen scraps, cooked food waste, and also compostable food packaging. The portable composters can be used on-site such as at home, food service outlets, or event sites, as the biotech filtering system of the portable composters able to neutralises foul odours (Wood, 2023).

Case Studies

Several case studies have highlighted successful implementation of these technological innovations in Asia.

In Japan, the government hopes to curb business-related food waste by over 20 percent between 2016 and 2030. Japanese companies are using AI and other technology to reduce the amount of food that never reaches consumers in response of combating food waste and to make production more efficient. Lack of human resources is one of the challenges faced by Japan, and it is expected that the working population will decrease by 40 percent by 2050. Thus, Asia-Pacific Economic Cooperation (APEC) Policy Partnership on Food Security argued that the use of AI and IoT for data collection and analysis are crucial for its food chain sustainability (APEC, 2019). The convenience store chain Lawson introduced an AI-based inventory management system that reduced food waste by 30 percent within the first year. Gaining an advantage, companies like Nichirei Foods and Calbee began at the top of the supply chain for a significant loss reduction. Nichirei Foods has developed and adopted an AI-powered system for detecting hard-to-remove bones in chicken meat and expected to reduce food waste from chicken processing by 80 percent in three years. Another issue faced by Japan in its initiative of combating food waste is with regards to the changes of weather (APEC, 2019). Despite this challenge, the leading tofu maker, Sagamiya Foods, is using data from Japan Weather Association to predict sales that are affected by temperature and managed to reduce annual cost by 10 million Yen (92,500 US Dollar) (Minai and Obayashi, 2019). Indeed, technology innovations improve food production and distribution, based on the analyses and forecast, and thus, help to reduce food waste in Japan.

In South Korea, the city of Seoul's partnership with the "No Food Waste" app resulted in the redistribution of over 100,000 meals within six months. The city made progress in 2013 when it fully implemented a mandatory "pay-as-you-waste" program for recycling food waste that complied with the National Government's enforcement guidelines, which prohibited the discharge of food wastewater into the ocean (ICLEI, 2019). The city also implemented a volume-based food waste fee system, whereby food waste must be disposed using either designated collection containers with payment chips for pick-up or prepaid standard waste bags, or to an automated bins equipped with scales and Radio Frequency Identification (RFID) systems that weight food waste as it is deposited, and charge residents using an ID card. The discharge food waste is collected by authorised transport and recycling business operators and converted into resources such as animal feed (64%), compost (33%) and bioenergy (ICLEI, 2019). 6,000 automated bins are placed in its capital city, Seoul, and the "pay-as-you-recycle" machines have reduced food waste in the city by 47,000 tons in six years. As a result of all these

attempts, South Korea that once recycled only 2 percent is now recycling about 95 percent of its food waste (Broom, 2019).

In Taiwan, the anaerobic digestion facility in Taichung processes 200 tons of food waste daily, generating enough electricity to power thousands of households. As Taiwan generates a huge amount of organic waste daily, anaerobic digestion through biological degradation processes can lead to reduction of waste and pollution, as well as regeneration of biogas energy (Heberlein, 2018). In Hong Kong, the facility for anaerobic digestion known as "O.PARK2" located at the northernmost district near Sha Ling, receives and processes about 300 tons of food waste per day, producing more than 45 GWh of electricity annually (Agrivert, 2023). The facility includes waste reception and waste pre-treatment system, anaerobic digesters, process to dewater the resultant digestate into a solid and liquid fraction, process to turn the solid fraction into granulate fertiliser, wastewater treatment plant, centralised air pollution control, biogas production and conditioning, as well as heat and power cogeneration plant. The treatment procedures are made custom to handle varying amounts and rates of organic waste, depending on the quantity and quality of food waste. The facility is designed and built to be energy efficient, minimise energy consumption, and export surplus energy to the public electricity grid.

In Malaysia, SWCorp started a pilot project of converting food scraps into organic fertiliser for crops in every state of Malaysia. Starting in 2023, the main objective of this initiative is to ensure that all food waste are not sent to the landfills. Food waste and scraps are placed into a machine, which are gradually combined with sawdust and rice husks for 48 hours. Being a Muslim-majority country, Malaysia collects even more food waste during the holy month of Ramadan, where bazaar is everywhere, and huge amount of food are thrown away daily. The Pahang state director of SWCorp, Mr. Sharudin Hamid, takes the initiative to place mobile machines at a park in the heart of state capital Kuantan, where it is easily accessible by the public. He claimed that on average, 25kg of scraps are being processed daily during Ramadan (Today Online, 2024). With this initiative, out of 14 states in Malaysia, Pahang reported the highest reduction of food waste in 2023 with 13.01 percent, followed by Kedah (5.57%), Perlis (3.71%), Johor (3.28%), and Melaka (2.49%) (Leong, 2024).

Meanwhile in Singapore, food waste from the local hawker centres has been converted into biogas to generate electricity since November 2021. About 150 kg of food waste were being collected daily from only 60 stalls at the East Coast Lagoon Food Village (Hong-Yi, 2021). The food waste is then transformed into electricity that is enough to power two phone charging stations for public use, and 31 wall fans at the hawker centre. In addition, the generated electricity is also used to power the anaerobic digestion system that converts the food waste into biogas and fertiliser. Although anaerobic digester has been used in some hotels in Singapore such as Marina Bay Sands, the NEA highlighted that the initiative to include this technology as an on-site treatment solution at the hawker centre is to close the food waste gap at its main source generators. In fact, the project at the hawker centre also integrates sub-systems such as waste bin loader, sorter, shredder, and feeder to enhance the system's performance. At the same time, the National University of Singapore (NUS) in collaboration with the National Parks Board (NParks), is working on a project of potentially using nutrient-rich liquid residues from digested food waste, known as digestate, as pathogen-free fertilisers around East Coast Park (Hong-Yi, 2021).

CONCLUSION

Technological innovations play a crucial role in addressing the food waste crisis in Asia. Smart inventory management systems, food sharing apps, and waste-to-energy technologies offer practical and sustainable solutions to reduce food waste and promote environmental and social well-being. By continuing to invest in and adopt these technologies, Asian countries can lead the way in creating a more sustainable and food-secure future. In fact, all these technologies are the key in addressing poverty, hunger, and climate change challenges. According to the United Nations, 870 million undernourished people could be fed by saving just one quarter of global spoiled food (Willige, 2023). In general, local governments in Asia are actively looking for ways to minimise food waste as part of their mission to lead citizens towards a sustainable future. Cooperation between government and private sectors play a vital role in ensuring the success of adapting technology innovation in the initiatives of reducing food waste. Meanwhile, technology has been essential in upgrading food waste management system, and maximising recycling rates. Importantly, the long-term solution to reduce food waste should begin from its source, and reintegrate the waste into the ecosystem. More research on technological advance for innovation are encouraged to improve the effectiveness of food waste disposal treatments.

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