Journal of Sustainability Science and Management
Volume 18 Number 8, August 2023: 211-229
eISSN: 2672-7226

A SYSTEMATIC LITERATURE REVIEW ON THE TECHNOLOGICAL APPROACH OF FOOD WASTE DISPOSAL AND ITS ENVIRONMENTAL IMPACT IN ASIAN COUNTRIES

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Submitted final draft: 15 May 2023 *Accepted: 21 May 2023* http://doi.org/10.46754/jssm.2023.08.015

Abstract: Food waste can be considered a global sustainability challenge due to its extensive environmental consequences and the fact that humans are unable to avoid food waste generation. This study aims to review the food waste disposal technological approach available in Asian countries and also its environmental impact towards the technology treatment. A significant amount of food waste can contribute to global warming while the use of disposal technologies may cause significant environmental issues, inspiring researchers to conduct various studies. Regrettably, previous findings about the effectiveness of food waste disposal were not stated clearly. As a result, this study explained how the use of food waste disposal technology treatment affects the environment. A systematic search strategy based on the guidelines of the Priority Report on Systematic Review and Meta-Analysis Review Protocol (PRISMA) was developed and implemented using three databases: ScienceDirect, Scopus, and Web of Science. 17 publications were yielded from the search attempt and will be studied in depth. The results summarized five common food waste disposal technology approach which is landfilling, aerobic digestion (composting), anaerobic digestion, incineration and animal feeding. These technologies have adverse effects towards the environment global warming potential, climate change damage and also towards soil, water and air pollution. Hence, more research is needed to investigate these issues.

Keywords: Food waste, landfill, anaerobic digestion, composting.

Introduction

Food waste is when people eat food that was not meant for them, animals eat food that was meant for humans, or food is thrown away that is still edible (FAO, 2014). This includes both part of food either edible or non-edible, that has been taken out from the food supply chain but may still be used again or managed through its disposal (Ostergren *et al.,* 2014). Three different types of food waste can be categorised into avoidable waste which is the food that was edible at one point but is now unusable, is the first thing to think about when you think about waste. The second type is unavoidable waste, which refers to things that cannot be eaten, like eggshells and the third one is avoidable food waste that refers to specific wastes that are sometimes, but not all the time, eaten, like the skin of potatoes (Papargyropoulou *et al*., 2014). Researchers said that these three main types of food waste can differ based on different cultures (Liu, 2014). Many countries, although some are in the planning and development stages, still lack a comprehensive food waste management system, including Malaysia (Thi *et al.,* 2015; Kasavan *et al*., 2019; Adam et al., 2022). To overcome the problem of food waste production, Malaysia has emulated other countries that have been successful in managing food waste well, among them are Japan, Thailand, Taiwan and South Korea. Among these countries, Taiwan was successful example in management strategies of food waste through specialized enforcement efforts and comprehensive government technology and it can serve as an example for other countries (Chang *et al.*, 2008).

Food waste issues have gotten enormous attention due to its serious volume, and unfavourable economic and social consequences (Schanes *et al*., 2018). The root cause for the increase of the food waste amount is due to changes in a person's eating habits and low awareness based on their standard of living, which allows them to obtain more food products and often results in food waste wastage (Nordin & Adman, 2019; Azmin *et al.,* 2022). When a person purchases or prepares more food than is required, the excess food is inevitably discarded. (Rohini *et al*., 2020). Similarly, when purchasing in excess so that the expiration date is exceeded, the food source spoils and becomes inedible. Most hotels, restaurants, and the food industry produce food in large quantities, which results in waste when not sold.

Furthermore, there are five major alternatives for the treatment and disposal of food waste in Asian countries which include aerobic digestion (composting), anaerobic digestion and fermentation, animal feeding, incineration, and landfilling. (Papargyropoulou *et al.,* 2014). Based on the five food waste treatments above, animal feeding and aerobic digestion are more prone to the reuse and recycling of food waste, which is why it is most preferred in food waste classification systems. Despite that, the use of these treatment and disposal technologies may cause significant environmental and human health issues, such as Greenhouse Gas (GHG) generation and climate change, and as the number of landfills grows, so does the number of rodents and insects that can spread disease to humans.

In this context, it will be focused on Asian countries as the most appropriate disposal measures for food waste management in Asia which were implemented by the policies of the regions. As a result, this study will reduce waste by effectively managing resources at the disposal level and improvement of each technology used which will improve the efficiency and safety of waste disposal. Hence this paper aims to point out the food waste disposal technological approach. This paper has the objectives to: (a) Determine the technology for food waste disposal in the Asian region and its impact on the environment; (b) Identify the types of food waste technologies treatment available; (c) Determine the impacts of various technologies towards the environment. Because of the topic's complexity, the findings and outcomes of previous studies have remained fragmented. A Systematic Literature Review (SLR) can assist in the assimilation and analysis of existing work in this discipline to allow a research framework that helps guide scholars and practitioners to be constructed (Denyer & Tranfield, 2009). The current study uses SLR methodology in answering the subsequent research questions (RQs) for the review: RQ1. What is the type of food waste technology treatment available in the Asian region? RQ2. Who will be affected and what impact will be obtained from the technology treatment?

Materials and Methods

The Review Protocol – PRISMA

This study was governed by PRISMA. PRISMA was chosen because it helps authors improve systematic review and meta-analysis reporting. PRISMA consist of a 27-point checklist used to improve systematic review transparency. PRISMA elements cover entire aspects of a manuscript, including titles, summaries, referrals, methods, results, discussions, and funding. The flow diagram of PRISMA shows the flow of information through the phases of a systematic review. Moreover, PRISMA will highlight the number of study records being identified, included and excluded, and the reason for the exclusion (PRISMA, 2020). It can be used to document systematic reviews for purposes other than the evaluation of interventions (Matthew J *et al.,* 2020). It was also specially designed for a systematic review and guidance in the environmental management field. The authors begin the SLR by developing a good research topic for the review. Then, the author moves on to a systematic search technique that can be categorised into three phases: "Identification," "screening (inclusion and exclusion criteria), and eligibility." The author, then, discusses the technique that is used to ensure that the studies under evaluation are rated as high, medium, or poor quality, and then proceeds to the quality appraisal of the selected articles. Finally, the author explains how the review's data is abstracted, as well as how to analyse and validate abstracted data. Figure 1 shows the flow diagram of the research question formulation that was adapted from PRISMA.

Formulation Research Question

The Research Questions (RQs) formulation of this study is according to WWH (Methley, 2014). WWH is a common tool that assists authors in formulating appropriate research questions for reviews. WWH refers to three main concepts, which are Who, What and How as shown in Table 1.

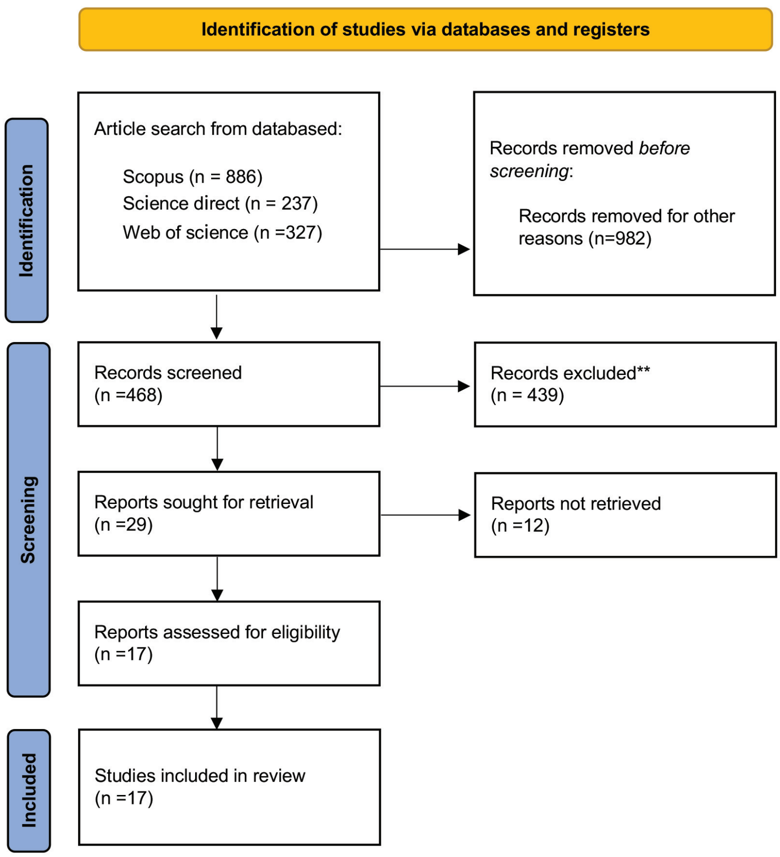

Figure 1: The flow diagram adapted from (PRISMA, 2020)

Table 1: Research Question tool

Who?	Who refers to who/whom will receive the impact from the food waste technology treatment
What?	What refers to the types of technology that will be used to dispose of the food waste
How?	How is based on how the impacts develop from the technology treatment?

Systematic Searching Strategies

Identification

Identification is a key keyword in research searching for synonyms which are food waste, disposal technique treatment (incinerator, composting, anaerobic digestion, landfill), and environmental impact. The goal is to provide more options for finding more review-related articles in the chosen database. The keywords (as shown in Table 2) were chosen based on the research question, previous studies, Scopus, Science Direct, and expert recommendations, as well as the identification procedure, which included searching an online thesaurus and dictionary. This database was selected due to it contains full-text articles either from journals or books, primarily published by Elsevier and sometimes hosted by several communities. On the three principal databases, Science Direct, Web of Science, and Scopus the author can improve on the present keywords search and generate a full search string using "Boolean operator, phrase searching, truncation, wild card, and field code functions". There are several advantages to using these three databases which have the potential to become the leading databases in the SLR, including advanced search capabilities, a comprehensive index with more than 5,000 editors, article quality control, and multidisciplinary methods, including research related to environmental management (Martin *et al.*, 2018).

Screening

The studies were identified through the database search by specifying them based on set inclusion and exclusion criteria shown in Table 3. The search process from these databases (Scopus, Science Direct, Web of Science) has resulted in 1450 articles. From the screening stage, only research articles published in English will be selected and will act as primary sources for the

Table 2: The search string

Database	Search String
Scopus	TITLE-ABS-KEY [("food waste" OR "organic waste") AND ("landfill*" OR "incinerator" OR "compost*" OR "aerobic* digest*" OR "anaerobic* digest*" OR "animal feed*") AND ("environment* impact" OR "environment* effect)]
Science Direct	[("food waste" OR "organic waste") AND ("landfill" OR "incinerator" OR "composting" OR "anaerobic digestion" OR "animal feeding") AND ("environmental impact" OR "environmental effect")]
Web of Science	TS= [("food waste" OR "organic waste") AND ("landfill*" OR "incinerator" OR "compost*" OR "aerobic* digest*" OR "anaerobic* digest*" OR "animal feed*") AND ("environment* impact" OR "environment* effect")]

Table 3: The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Timeline	2010 to 2020	< 2010
Language	English	Non- English
Source Type	Article Journal	Article Review, Books
Regions Keywords	Asia Country Food waste, organic waste, landfill, incinerator, composting, aerobic digestion, anaerobic digestion, animal feeding, environmental impact, environmental effect	Non-Asia Country Non-Food waste, organic waste, landfill, incinerator, composting, aerobic digestion, anaerobic digestion, animal feeding, environmental impact, environmental effect

review. The timeline was selected from 2010 to 2020 by looking at the maturity of the study. Other than article journals such as book series, article reviews, newspapers and document types were excluded and the Asian regions were selected for the review.

Eligibility

The next phase was eligibility, during which the retrieved articles were screened, manually, to ensure that all articles met the criteria. This is accomplished by reading the document's title and summary.

Quality Appraisal

During the quality appraisal stage, each identified previous study was evaluated. The primary goal of the quality assessment of the studies was to analyse and include studies that answered the research questions, as well as to provide support for more in-depth research on the set inclusion and exclusion criteria. The quality appraisal process in this study follows and adapts from Alsolai and Roper's (2019) quality appraisal questions. The questions were made up of 15 questions, and the author will give each one a score based on how well it answered the question. The score rank is classified into four stages, which are excellent ($13.5 \leq$ score ≤ 15), good ($9.5 \leq$ score ≤ 13), fair ($5 \leq$ score ≤ 9), and fail ($0 \leq$ score ≤ 4.5). Eleven articles were rated as excellent and six as good as a result of this method. Based on the outcome of the quality appraisal, 17 of the appraised articles were eligible to be included in the review.

Data Extraction and Analysis

The final process in this review was data extraction and analysis. In this section, we chose to consider integration to analyse the final article together. As mentioned by Whittemore and Knafl (2005), the method was designed to be a consistent method of any integrated review, comparing and identifying patterns (quantitative, qualitative and mixed-method) in extracted data and systematically classifying, transforming, themes and relationships of data. When data is analysed, it is done systematically to make sure there isn't any bias or mistakes. The review's findings will also be taken more seriously if people read the review and take it seriously (Pannucci & Wilkins, 2010).

Whittemore and Knafl (2005) state that qualitative or mixed-method techniques allow researchers to conduct repetitive comparisons over primary data sources which can be the best way in synthesising or analysing integrative data. In this study, the qualitative technique was chosen and used. The researchers read the 17 articles and focused on the articles' abstract, results and discussion parts. Following the research questions, data extraction was done. This means that any data analysed from the studies could and may provide answers to the research questions and were extracted before being tabulated in the review. Then, the researcher used thematic analysis to find themes and sub-themes through their efforts to determine patterns, themes, clusters, scores, similarities, and relationships in the extracted data (Braun and Clarke, 2006). Moreover, thematic analysis is thought to be the best way to combine mixed study designs (integration) (Flemming *et al*., 2019).

To begin the thematic analysis, themes must first be generated. At this point, the authors must attempt to identify any patterns in the articles and extract the data from all of the reviewed articles. All relevant data were extracted and organised into four major groups. The authors went over the four data groups again and discovered twelve new subgroups. The next step was to double-check the information. Authors need to re-examine all major and sub-themes developed to guarantee data accuracy and relevance. The authors, then, need to name the themes in each group and subgroup starting with the main group's themes first, then the subgroups' topics. This method was used to build topics in a group of co-authors and the corresponding author. This process continued until the researchers agreed to reconcile the established theme and subthemes. An experienced panel in qualitative methodologies and community development research reviewed the created themes. A total of twelve subthemes were assigned to experts. They agreed the topics and subtopics were reasonable and in line with the review's conclusions.

Results

Background of Selected Data

The review was successful in obtaining 17 selected articles. Four themes were developed based on the thematic analysis: Type of food waste, technology in food waste disposal, the common technologically advanced method of disposal, and environmental impact (Table 4). These studies were conducted in Asian countries such as China, Malaysia, Qatar, Iran, South Korea, Turkey, and Singapore. One of the 17 articles chosen was published in 2011, 2013, 2014, 2015, 2018, two in 2016, and five in 2019 and 2020 (Figure 2).

Themes and Sub-Themes

Types of Food Waste

There was a massive amount of food waste being produced and generated were Household Food Waste (HFW), Waste Cooking Oil (WCO), and Catering Food Waste (CFW) in Qatar, Malaysia, Japan, Hong Kong, Seoul, and Beijing. After you eat, FW only refers to leftovers. It includes HFW, CFW, and WCO, which are all types of leftovers. CFW was found in a wide range of restaurants, snack bars, canteens, hotels, and bar rooms. Eggshells, bones, vegetables, fruits, expired food, leftovers, and other items are examples. WCO was an extra component of CFW that can be collected from catering businesses. It contained waste from gutter oil, frying oil, and swill, all of which were individually collected and handled for reuse or recycling by generators or collectors (Wang *et al.,* 2017). In Hong Kong, around 3584 tonnes of food waste are generated every single day, with household waste accounting for roughly 70% of this total. Disorganised food handling, packaging, transportation, overstocking of certain foods, and improper storage cycles all contribute to this type of food waste. In addition, platters are responsible for a substantial amount of the trash produced by food services, and significant amounts of waste produced by food services are generated by leftovers, which are not collected in some countries for reasons

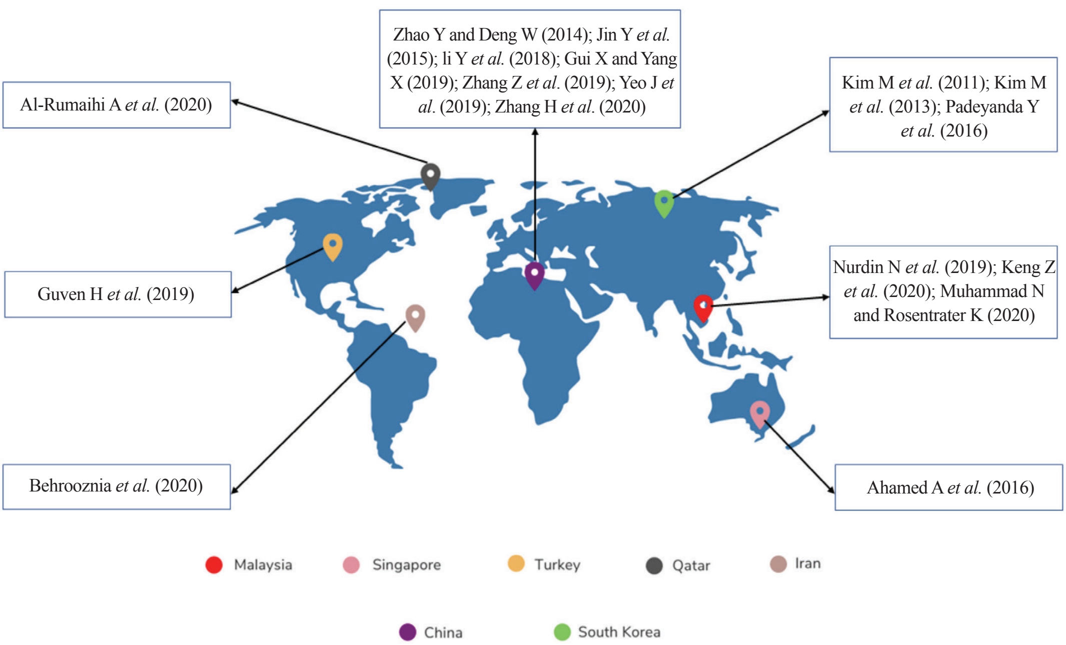

Figure 2: Food waste disposal technology area in selected Asian countries

related to food safety because of food safety concerns, food safety guidelines, and greater feed portions.

Food Waste Disposal Technology

Aerobic digestion was the first sub-theme under food waste disposal technology. Aerobic digestion, also known as composting, is based on aerobic bacteria rapidly consuming organic matter, from which microorganisms produce Single-celled Proteins (SCPs), water, and carbon dioxide (Arvanitoyannis *et.al,* 2008; Butnariu *et al.,* 2021). Glucose is converted into carbon dioxide and methane in compost. With a total moisture content of about 50%, a biofilm will form around each particle in the compost heap. The air will pass through the compost heap's pores and cross the water layer, providing oxygen to the microorganisms that live on the surface of the particles. Compost contains oxygen, which allows complex molecules to decompose into simpler components. Food waste composting is influenced by physicochemical factors such as temperature, pH value, humidity, and composting material (C:N ratio) (Chang *et al.,* 2006; Wang *et al.,* 2018). In general, there are three-phase processes in composting which include phases such as mesophilic, thermophilic, cooling, and maturation (Chowdhury *et al*., 2013). During the mesophilic phase, psychrophilic and mesophilic bacteria proliferate and produce heat by microbial respiration and the metabolism of basic organic molecules such as sugars, lipids, and proteins. A Malaysian study found that efficient composting requires the right ratios of food waste and bulking agent, resulting in a ratio of carbon-to-nitrogen of approximately 30 with a moisture level of 50-60%. As the temperature of the composting pile rises, the moisture level of the process needs to be maintained at approximately 55-60% through watering, evaporation, or pile turning (which may differ based on the local climate). It's worth noting that high temperatures in this stage aid in pathogen and organic waste sanitization, as temperatures more than 55°C are required to kill microorganisms (Tian *et al.,* 2012). In a community-scale composting system where six tonnes monthly capacity of food waste which matures in around seven months will produce around 11% wet basis or 30% dry basis of compost product relative to waste input of total organic (i.e., approximately 660kg compost/month). The resulting compost's quality demonstrates the method's success, as it complies with Malaysia's SIRIM MS1517:2012 organic fertiliser standard of organic matter, Carbon/Nitrogen (C/N) ratio, moisture level (W), Total Kjeldahl nitrogen (TKN), Phosphorus (P), and Potassium (K) values of 52.5%, 12%, 2.62%, 3.39% and 0.58% respectively.

Second, we looked at anaerobic digestion as a separate topic (AD). In an oxygen-free environment, microorganisms break down organic matter into biogas such as CH_4 and CO_2 through processes such as hydrolysis, and acid and methane fermentation (Parajuli *et al*., 2014). In Iran, it was used to generate electricity by burning it in the engines, and heat generated from the electricity generation using the engines was utilized to heat the digesters. The digestate is used as a nutrient on land. These methods should help in reducing greenhouse gas emissions by decreasing the amount of CO emitted. Biogas which is commonly used as fuel consists of elements such as carbon dioxide (CO_2), methane (CH_4), hydrogen (H_2), carbon monoxide (CO), ammonia (NH_3), water (H_2O), hydrogen sulphide (H_2S), and traced amount of oxygen (O_2). Furthermore, it is known that it can also be used in combined heat and power (CHP) plants for electricity and heat production (Kythreotou *et al.,* 2014). It can be considered as a source of clean and renewable energy with the potential to sustainably generate electricity and heat by replacing fossil fuels. In other words, using biogas derived from MSW instead of fossil fuels can save money on fuel while also improving energy security and lowering harmful releases to the environment (Whiting & Azapagic, 2014).

Landfilling is said to be a time-honoured method in waste management, as the EPA reports (2018). This method of disposal will require a considerable amount of land and will be expensive, as well as having a negative influence on the ecosystem (Kim & Kim., 2010; Xu *et al.,* 2018). A study by Gao *et al.* (2017) has reviewed the impact of landfills on climate change is tenfold that of composting, incineration and anaerobic digestion, implying that this strategy will considerably exacerbate global environmental concerns. Currently, landfilling is considered a primary method for food waste disposal in Hong Kong. However, landfilling has environmental drawbacks which include emission of greenhouse gas (GHG), odours, and leachate concerns. It can be said that more than 90% of Hong Kong's degradable organic waste is made up of food waste, which accounts for practically all landfill gas emissions (HKEPD, 2012). In situ measurements of landfill gas composition revealed that 53.8% was CH_4, 39.6% was CO_2, and the remaining were CO, H_2S, and H_2 with concentrations accounted for 0.001, 0.00002, and 0.05 g/m^3, respectively. The landfill generated 30,000 MWh of electricity annually at a rate of efficiency of 29.1%, according to a study on operational data from its electric generators. As a result, 6900 t/y of methane was supplied into the system, with an additional 990 t/y recorded as being flared. The release rate was also measured in situ, and it was found that roughly 2000t of CH_4 was emitted each year. An appropriate estimate predicted that 70% of landfill gas is used to generate electricity, 10% for flare, and the remaining 20% is emitted during peak gas production from the work surfaces or cover layers. It was not possible to use landfill gas for heat recovery. In Korea, however, the disposal of raw food waste was outlawed in 2005 which is due to social issues that affect the local community, such as odour accumulation and the creation of soluble water, this is not recommended.

Incineration technology entails the combustion process and the conversion of chemical energy to generation of electricity and heat. Even though it has the potential to reduce food waste (FW) by up to 85%, incineration has received little support in some countries, primarily due to the toxic air emissions produced by incineration. Additionally, FW contains high moisture content which reduces combustion efficiency in the system and may make it economically impractical (Pham *et al.,* 2017). The burning of pure food waste with the subsequent recovery of energy has not garnered much attention in Turkey due to the waste generated in the country containing a high amount of moisture and the presence of components and elements that are not combustible in the generated waste. Certain concerns exist about incineration, including the emission of harmful and heavy metals and the necessity for bottom ash and fly ash disposal.

In Korea, dry feeding and wet feeding were the key strategies for managing food waste, especially in Jungnang District located in northeastern of Seoul. This district accounted for 3% of Seoul's land area and is composed of mainly residential areas (57.8%) followed by green areas (40.4%), commercial areas (1.7%), and a small portion of semi-industrial areas (0.1%). In 2008, Jungnang District had 111,298 houses and a total population of 429,404 created 81 tonnes of food waste per day per single-family home (9.8%), townhome (34.1%), apartment (35.3%), and restaurant (13.6%). Dry feeding treated approximately 50%, 31%, and 19% of the created food waste in 2008–2009, respectively. Dry feeding (DF) is a method of feeding animals that involves sifting, shredding, and drying food waste. Wet feeding (WF) was generated by sifting, shredding, and heating food wastes, and the finished product was generally 22% moisture. The final product, which had around 69% moisture, was fed to animals.

Environmental Impact

Food waste not only wastes resources, but also contributes to severe climate change, as well as soil, water, and air pollution. Food waste from households, restaurants, and other sources was a significant contributor to these impacts. Most Asian countries, including China, South Korea, and others, have similar impacts on disposal of FW. FW is frequently disposed of in landfills, releasing significant volumes of GHG such as methane (NH_4), carbon dioxide (CO_2), nitrous oxides (N_2O) and chlorofluorocarbon (CFC) (Khor, 2015). As well as releasing greenhouse gases, landfills discharge toxic leachate that contains high concentrations of organic and inorganic toxins that could harm wildlife, plants, and the water table and surface, while posing a serious threat to the ecosystem (Xu *et al.*, 2018; Sackey *et al.,* 2020).

The landfill has significantly contributed to environmental issues such as global warming due to the emission of gases from the landfill. The GHG will cause global warming and warm the earth by absorbing the large amount of GHG. Different GHGs can have different effects on the Earth's warming (US EPA,2021). GHGs from food loss and waste disposal are predicted to contribute to the emission of 3.3 billion tonnes of CO_2 equivalent to the global atmosphere each year (Paritosh *et al.,* 2017). When it comes to the treatment of FW, the majority of GHG emissions come from direct emissions which can be created in anaerobic circumstances by degradation of organic waste in the sanitary landfills, and they account for approximately one-third of the total GHG emissions. According to research that was carried out in China, in 2018, the total GHG emissions that were caused by the treatment of sewage in China accounted for roughly 4% of the total GHG emissions that were caused by the burning of fuel in Asia (excluding China) in the previous year (IEA,2017). In comparison, based on national fossil fuel combustion, GHG emissions of countries can be noted as such as the "Philippines (104 Mt CO_2e, Coal) and Vietnam (102 Mt CO_2e, Coal) in Asia, Egypt (120 Mt CO_2e, Coal) in Africa, Belgium (93 Mt CO_2e, Coal) and the United Kingdom (89 Mt CO2e, Coal) in Europe, Canada (75 Mt CO_2e, Coal) in North America, and Venezuela (90 Mt)".

Composting can help eradicate degraded organic waste. Degradable organic wastes are also known as biodegradable wastes (Shafy & Mansour, 2018). Composting, on the other hand, provide viable means of safely using a variety of organic wastes to convert them into products that can be used as organic fertilizers. Uncontrollable fabrics, polyethylene bags, plastic bags, etc., however, cannot be composted. Composting can be regarded as a safe way to get rid of organic waste, but it also makes a lot of odours and releases a lot of greenhouse gases (CO_2, SO_2, and NO_2). Based on how much nitrous oxide (N_2O), CH_4, and CO_2 are emitted, the composting scenario calculates how much climate change damage will be caused by this. CO_2 equivalents are used to figure out how many kilogrammes of CO_2 these emissions would make. It is worth noting that compostable materials such as food waste and paper may decompose and release methane, which is occasionally captured and converted to energy. As a result, composting significantly reduces GHG emissions, notably methane. Additionally, air emissions from composting and composting on land may contribute to nutrient enrichment and acidification as a result of the loss of Sulphur and Nitrogen in various forms.

Another bad thing about waste is that it leads to the pollution of the water. It is said that about 1400 people die each day because of water and water-related problems and diseases. Water bodies like rivers, streams, and oceans can be harmed by the wastes that get into them. These wastes can lower the pH of the water and make it toxic for aquatic animals and human beings who use the water. Moreover, some of the pollutants are not so easy to dissolve in water, and they are very good at getting into your body's fat (Varjani *et al.*, 2017). Reports show that water bodies are full of toxic metals, which can harm people (Corral *et al.,* 2019; Sahay *et al.,* 2019; Holanda & Johson, 2020). Water from a source that is polluted with waste in one place could be used in another area by other people. Soil pollution, too, can be caused by improper management of waste. Disease-carrying bugs can be found in waste that is thrown away haphazardly. Metals that come from iron, radioactive waste, or other sources are bad for plants and soil organisms leading to lower crop productivity (Mani & Kumar, 2013).

The next sub-theme is Life Cycle Assessment (LCA). LCA is a way to figure out how a product or system might be bad for the

Table 4: The themes and sub-themes

	Studies	Year	Region	Types of Food Waste		Food Waste Disposal Technology					Environmental Impact				The Most Technologically Advanced Method of Disposal
				HW	**OT**	**CP**	**AD**	**IN**	**LF**	**AF**	**CE**	**SE**	**AE**	**WE**	**AD**
1	Kim M *et al.*,	2011	South Korea	/		/	/	/	/	/	/	/	/	/	
2	Kim M *et al.*,	2013	South Korea	/		/		/	/			/	/	/	
3	Zhao Y and Deng W	2014	China		/	/			/			/		/	
4	Jin Y *et al.*,	2015	China		/		/				/				
5	Padeyanda Y *et al.*,	2016	South Korea		/	/						/			
6	Ahamed A *et al.*,	2016	Singapore		/		/	/			/		/		/
7	Li Y *et al.*,	2018	China	/			/				/				/
8	Gunasegaran *et al.*,	2019	Malaysia	/		/						/			
9	Guven H *et al.*,	2019	Turkey	/			/	/	/		/		/	/	
10	Guo X and Yang X	2019	China		/	/	/			/	/	/			/
11	Zhang Z *et al.*,	2019	China		/	/	/	/	/	/	/	/	/	/	/
12	Yeo J et al.,	2019	China	/		/			/			/		/	
13	Al-Rumaihi A *et al.*,	2020	Qatar		/	/	/				/	/			/
14	Zhang H *et al.*,	2020	China	/			/	/	/		/		/	/	/
15	Keng Z *et al.*,	2020	Malaysia		/	/			/			/		/	/
16	Behrooznia L *et al.*,	2020	Iran	/			/				/				/
17	Muhammad N and Rosentrater K	2020	Malaysia		/	/			/			/		/	/

Note:

Types of food waste	**Food waste disposal technology**	**Environmental impact**	**The most technologically advanced method of disposal**
HW = household waste	CP = Composting	CE = Climate effect	AD = Anaerobic digestion
OT = other	AD = Anaerobic digestion	SE = Soil effect	
	IN = Incineration	AE = Air effect	
	LF = Landfilling	WE = Water effect	
	AF = Animal feeding		

environment and how it might affect people (ISO, 2006). It can be considered a scientific way to look at the impact of products or environmental management on the environment. It's used a lot in other countries in Asia, and it can show how much energy and resources are used and how that affects the environment (Wang *et al.,* 1999). In Qatar, LCA was used to assess and compare the environmental impact of two food waste composting techniques which are: (1) Windrow composting and (2) Hybrid Anaerobic Digestion (AD). This LCA is mainly used to assess the impact of products, processes, or activities on the environment in its entire treatment life cycle (Zhou *et al*., 2018). LCA substitutes a specific assessment of the entire process compared to the traditional abstract assessment of a single component.

In a way, LCA avoids any limitations of traditional environmental impact assessments and effectively quantifies impacts on the environment (Rebitzer *et al.,* 2004). This is becoming more valuable and popular, and LCA is also widely used in the environmental engineering field. It was an efficient method for estimating, assessing, comparing, and developing products and services based on their possible environmental implications (Rebitzer *et al.,* 2004). LCA has investigated different types of agricultural waste processing technologies which include composting, anaerobic digestion, fermentation, and incineration (Prapaspongsa *et al*., 2010; Jury *et al.,* 2010; Lansche & Müller, 2012; Luo *et al.,* 2014). LCA consists of four steps: (1) Objective and scope, (2) Inventory analysis, (3) Potential impact assessment, and (4) Explanation of results (Gentil *et al.,* 2010). An LCA assessment enables government bodies to make informed decisions about future waste management technology (Khoo *et al.,* 2010). Environmental life-cycle assessments assist decision-makers in comprehending any technology from an environmental perspective and identifying the most appropriate technology for the country.

The Most Technologically Advanced Method of Disposal

A study conducted in an Asian country has indicated that Anaerobic Digestion (AD) technology is a highly viable option for managing Food Waste (FW). This technology has been widely recognised as a more energy-efficient and environmentally-friendly method of treating FW compared to existing conventional methods like landfilling (Tong *et al.,* 2018; Moulta *et al.,* 2018). Numerous research indicate that biological processes such as AD and composting can be utilised to indefinitely manage organic materials (Xu *et al.,* 2015; Lin *et al.,* 2019). Previously published results of an environmental study on food waste indicated that anaerobic digestion–aerobic composting had the lowest environmental impact, landfilling had a moderate impact, and incineration had the greatest impact on the environment. According to Bernstad and la Cour Jansen (2011), incineration outperforms composting but has a greater environmental impact than AD. Ahamed *et al.* (2016) conducted a comparative analysis of incineration, anaerobic digestion (AD), and biodiesel production. The study revealed that incineration exhibited the poorest Life Cycle Assessment (LCA) performance across all impact categories, which include eutrophication, acidification, Global Warming Potential (GWP), and cumulative energy demand. Overall, AD is the most commonly used and technologically advanced method in Asian countries and has the highest economic benefits of all the published publications reviewed (Xia *et al*., 2015).

Discussion

Four themes and twelve subthemes emerged from the thematic analyses. This section expanded on the various types of food waste. Food waste originating from households, restaurants, catering, and institutions was all mentioned in the reviewed article. Households account for the vast majority of food waste. Food spoilage, over-preparation, over-buying, and poor planning are all major contributors to Household Food Waste. Institutions such as hotels, schools, and hospitals generate an additional 7 to 11 billion pounds of food waste per year. Besides, oversized portions, chain store management inflexibility, and an extensive menu selection were among the factors that contributed to food waste in restaurants. Many wealthy countries have different approaches to dealing with food waste. In the United States, for example, people dispose of food waste in their kitchen sinks using a food waste disposer, which sends it to the sewers. Only 3% of the 31 million tonnes of food waste collected in 2011 was composted, with the remainder either burned or discarded (Gustavsson *et al.,* 2011; Thyberg & Tonjes, 2016).

Gunasegaran *et al.* (2019) stated that kitchen waste in Malaysia was either composted or fed to animals kept and lived at the hotel or on their estate such as in Balik Pulau. Composting was being used to keep food waste from ending up in landfills (Keng *et al.,* 2020). Composting is a popular alternative to dumping food waste in landfills, incinerating it, or turning it into animal feed. Composting can improve soil and reduce the need for chemical fertilisers. Composting helps to protect the environment. Sustainability aids in the retention of soil particles, thereby preventing erosion. It improves retention. Dispose of in a secure location. It is a simple product to use. They help with bioremediation. The floor has been contaminated. Furthermore, it benefits biodiversity. It attracts beneficial insects, bacteria, and fungi to cultivated plants and aids in soil formation where they are treated inside a closely monitored environment where they do not survive to stay indefinitely.

Composting also has several other advantages, such as cost savings, resource conservation, soil improvement, and reduced environmental impact. Economic benefits result from eliminating the need for chemical fertilisers, thus, reducing embodied water and energy resources, as well as associated emissions. Moreover, composting helps to conserve natural resources by increasing the soil's moisture retention capacity, which reduces the need for irrigation (Transportation., 2011). Composting reduces greenhouse gas emissions (GHG) as a result of the food waste disposal in landfills which generated greater air emissions being eliminated from landfills and when compared to composting, do not produce any environmental benefits. Furthermore, composting creates beneficial compost which reduces the need for chemical fertiliser, the production of which requires energy and emits greenhouse gases. Moreover, by reducing the use of chemical fertilisers, less environmental impact can be expected as it decreases the changes of chemical fertiliser runoff, which can cause algae blooms in rivers, lakes, and streams.

Food waste, like municipal solid waste, can be disposed of in landfills. Although landfills can be well-constructed and maintained which are safer compared to open dumping sites, the landfill will eventually fill up over the years and may leak the waste into the environment after several years. As a result, landfills should be used only for waste that cannot be reused. A simple landfill is made up of a hole with lining to protect its bottom (help to prevent groundwater contamination) where garbage is buried in layers, compacted, and then, covered. Moreover, to prevent any animals from digging up garbage, spawning flies, and the wind from spreading odours, waste (such as plastic bags), and pathogens, the dumped refuse should be covered with 0.5 metres of dirt at the end of each day (Harvey *et al.,* 2002). The more advanced ("engineered") types of landfills have liners at the bottom and side of the landfill and are designed with a leachate removal system that consists not only of leachate treatment but also gas extraction, groundwater monitoring, and cap system. Landfill capacity is planned while its location is chosen through environmental risk assessment (UNEP 2002). Even though landfills are the oldest form of waste management, we have discovered that they are no longer beneficial to our world. Toxins eventually end up in landfills, where they slowly infiltrate the earth and groundwater. Arsenic and household cleaners are among the hazardous substances. Toxic liquids leaking from landfill debris can quickly contaminate our rivers. Food waste was frequently dumped with MSW in Korea until 2005, causing odour and leaching issues for residents. In Korea, its government implemented the EU Landfill Directive (1999/31/EC) in 2005 to prevent the direct landfilling of food waste. Besides, the incineration of pure food waste has not been extensively researched despite its high moisture content and incombustible components. The most important gaseous products of waste incinerators, like other incinerator processes, are carbon dioxide and water vapour. Furthermore, as with many combustion processes, by-products such as soot particles and other contaminants are released into the exhaust gas, resulting in a non-flammable, partially burned waste residue (bottom ash) from the combustion chamber that must be discharged. It will be disposed of properly. The composition of the gaseous and solid residues generated during incineration is influenced, to some extent, by the waste stream composition that is being introduced into the incineration facility. The incineration process has been associated with the emission of hazardous substances such as toxic emissions and heavy metals. Additionally, the disposal of bottom and fly ash has also been identified as a significant concern. The implementation of energy recovery units can be accompanied by advanced off-gas control systems, which can effectively mitigate the detrimental impacts of air emissions. Additionally, food waste incineration has a high potential to generate environmental credits (Pham *et al.,* 2015). Other waste management activities, such as waste generation reduction, reusing materials, and waste recycling for use as raw materials in various manufacturing processes, may alter the configuration of this feed stream. Even though it is more expensive and requires a lot of monitoring equipment, incineration is usually preferable to landfilling waste (Astrup *et al.,* 2015; Thi *et al.,* 2015). Moreover, when energy and organic fertiliser can be used to replace non-renewable heat, electricity as well as inorganic fertiliser, Anaerobic Digestion (AD) can also be the best alternative for food waste treatment because it saves the most CO_2 and SO_2. Furthermore, AD has much lower environmental impacts compared to incineration with energy recovery, except when looking at Particulate Matter Formation (PMF), Marine Eutrophication (ME), Terrestrial Acidification (TA) as well as an Agricultural Land Occupation (ALO). Food waste AD is preferable compared to incineration and landfilling for the vast majority of environmental effect categories (Slorach *et al.,* 2019). Despite having a lower GWP than incineration, digestate application on land results in nutrient enrichment and acidification (Bernstad & la Cour Jansen, 2011).

Conclusion

The purpose of this research is to conduct a systematic review of the treatment of food waste disposal and its environmental impacts in Asian countries. The public, researchers, and environmentalists can learn and evaluate which treatment is best to implement and use based on the review. The findings show how food waste is processed and the effects of the treatments used, such as the effects on climate change, air, soil, and water. The review concludes that anaerobic digestion is the best treatment because it produces the fewest environmental impacts when compared to others. This study suggests that future scholars conduct additional research in Asian countries such as Malaysia, Singapore, Thailand, South Korea, Turkey, Qatar, and Iran due to a lack of research in these countries. Furthermore, government assistance in the form of economic, social, and environmental support is required in each country to strengthen and improve the effectiveness of food waste disposal treatment.

Acknowledgements

The author wishes to express gratitude and appreciation to the ethics committee for granting permission to carry out this research.

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