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Environmental assessment of casual dining restaurants in urban and suburban areas of peninsular Malaysia during the COVID-19 pandemic

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Abstract Food waste has been considered a global problem due to its adverse impacts on food security, the environment, and the economy; hence needs urgent attention and action. Its generation is expected to increase as the world population grows rapidly, leading to more global waste. This study sought the impacts of the COVID-19 outbreak on the 1-week operation of selected casual dining restaurants in urban (Ampang, Kuala Lumpur) and suburban areas (Kota Bharu, Kelantan and Jasin, Melaka) of Peninsular Malaysia, as the local community adjusted to life with COVID-19. The food waste in this study was classified into three categories: preparation loss, serving loss, and customer's plate waste. Our material flow analysis revealed that the highest food loss at these locations came from preparation loss (51.37%), followed by serving loss (30.95%), and preparation loss (17.8%). Meanwhile, the total average electricity consumption and its carbon footprint for Ampang were 127 kWh and 13.87 $kgCO_2e$, Kota Bharu 269.8 kWh and 29.47 $kgCO_2e$, and Jasin 142.2 kWh and 15.54 $kgCO_2e$, respectively. As for water, Ampang exhibited 22.93 m^3 total average consumption and 7.91 $kgCO_2e$ greenhouse emissions from this source, Jasin consuming 17.11 m^3 of water and releasing 5.88 $kgCO_2e$ of carbon footprint, while Kota Bharu emitted 20.21 $kgCO_2e$ of greenhouse gases from its 58.71 m^3 water consumption. Our findings indicate a major 'food leak' at the preparation stage, from which the waste could be utilised as livestock feed, and that electricity consumption is a greater carbon emitter than water consumption, suggesting a need for improvement to the kitchen practices and equipment.

Keywords Foodservice industry · Waste generation · Material flow analysis · Carbon footprint · Pandemic outbreak

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Introduction

The escalation of development globally has affected the demand for services, technologies, food, energy, and water. All those demands have their own detrimental

consequences on the environment and human beings (Jayachandran, 2022). As population and demand grew over the years, the establishment of restaurants, including casual dining restaurants, also experienced sustainable growth in Malaysia (Kueh & Ho Voon, 2007). Furthermore, there is an escalating number of eating-out behaviour among the Malaysian population (Lee et al., 2017). Other sectors under the foodservice industry are also not excluded from the steady development of the industry, from hotels to food retail, catering, health foodservice, and food manufacturing (Othman et al., 2021). The key to the booming of this industry is these sectors' capability to provide consumers with a pleasing experience.

Malaysia is one of the Asian countries that has many cultural and traditional foods, making it known as a food paradise. This recognition, however, comes with a price, which is food waste. Almost one-third of the food produced for human consumption leads to the generation of 1.3 billion tonnes of global food waste per year, which occurs throughout the supply chain (FAO, 2011; Papargyropoulou et al., 2016). Further, Malaysia Solid Waste Management and Public Cleansing Corporation reported that around 17,000 tonnes of food were discarded daily by Malaysians, which could feed about 12 million people (SWCorp, 2018). One contributor to this waste generation is massive food production in the foodservice industry, whereby supply exceeds consumers' demand (Barnhill & Civita, 2020; Pirani & Arafat, 2014). Besides, improper food waste management in the foodservice sector is one of the main reasons that leads to massive food waste generation (Thi et al., 2015). This can be due to the lack of food preparation and waste management skills, which may lead to waste pollution and odour problem.

As the COVID-19 pandemic struck Malaysia, the government decided to restrict travel and social interactions, termed as 'lockdown', to curb the spread of COVID-19 (Fan & Cheong, 2021; Tang, 2022). For instance, the number of people in one store at a time was extremely cut down, while the foodservice sector, such as casual dining restaurants, could only operate through home delivery or take-away. This situation made the production of food waste decline as the restaurant owners carefully planned the amount of food to be prepared as customers preferred to cook at home more compared to dining out during the pandemic (Liu et al., 2021; Qian et al., 2020). The electricity and water consumption were also lower than before the pandemic. However, there was an increase in food quantity bought by households due to fears of food supply disruptions (Pappalardo et al., 2020). In November 2021, the lockdown was fully lifted in Malaysia, and casual dining restaurants were fully opened where customers could dine in with their families. As the foodservice industry returns to normal, so does customers' behaviour whereby they order more than what they can eat, contributing to food waste. Besides, electricity and water consumption also increase to prepare food for the customers during operation hours, consequently affecting the environment (Tollefson, 2021).

For this study, the type of restaurants selected was casual dining restaurants located in Malaysian urban (Ampang, Kuala Lumpur) and suburban areas (Kota Bharu, Kelantan and Jasin, Melaka). A casual dining restaurant can be defined as a restaurant with a fun and comfortable ambience that serves food at an affordable price. People tend to dine at these restaurants due to their family-friendly surroundings too. The restaurants may also serve various types of food for breakfast, lunch, and dinner during their operation time, giving customers more food choices. However, they have created a substantial environmental footprint from the emissions released during livestock production to the water used in the food supply chain and the food waste generated along the way. The usage of energy and water sources by these restaurants will increase the carbon footprint, contributing to environmental pollution.

Importantly, there is limited information on how food waste produced from the foodservice industry amidst the COVID-19 outbreak could influence the carbon footprint generated from this sector. These food waste and carbon footprint quantifications are essential to enable the detection of 'food leaks' along the food supply chain so that optimal approaches can be taken where they are needed, in line with the growing circular economy concept (Tamasiga et al., 2022). Moreover, most of the recent literature reporting on the pandemic effects on food waste only focused on the changes in the food waste behaviour of the households and general society (Burlea-Schiopoiu et al., 2021; Filho et al., 2021; Lahath et al., 2021; Qian et al., 2020; Scharadin et al., 2021). These behavioural changes towards food waste as society adapts to the new norm may also affect the operation of foodservice establishments. Hence, this study assessed how

the pandemic influenced the generation of food waste and carbon emissions from Malaysian casual dining restaurants during their daily operation. Furthermore, these data will allow restaurant management to adopt sustainability and circularity knowledge and implement appropriate solutions to tackle these environmental issues.

Material and methods

Experimental design

Generally, this study involved four phases: preparation, implementation, data collection, and data analysis (Fig. 1). The preparation phase started with reviewing all the checklists and making sure all the necessary equipment was sufficient. Meanwhile, the implementation phase was by conforming all staff understood well the requirement to separate the food waste into three sections: preparation loss, serving loss, and customer's plate loss. The initial meter readings for water and electricity consumption were also recorded at this phase. For the data collection phase, the food waste amount at the end of the restaurants' operation hours was measured accordingly. The final meter readings for water and electricity consumption were recorded at this phase to determine the carbon footprint of each casual dining restaurant in this study. In the last phase, all the obtained data were analysed, followed by data interpretation. A flow diagram of the detailed data collection plan for the daily operation assessment of casual dining restaurants is illustrated in Fig. 2.

With some appropriate criteria (similar operating hours, eateries' information, and the number of customers per day), five casual dining restaurants in each district, Ampang, Kota Bharu, and Jasin, were selected to obtain and identify the amount of food waste produced for a 7-day duration. The reason behind the small sample size and the short study duration was because of the restricted funding for this study. Furthermore, the chosen number of food establishments and period of study were supported by previous literature (Silvennoinen et al., 2019), indicating a sufficient sample size to conduct a food waste case study. The number of employees, hours of operation, method of waste disposal, and expected number of customers were also recorded, whereby these data were obtained from the restaurant owners or managers, who were in charge of those records. This study was conducted during the Recovery Movement Control Order before a second total lockdown was implemented due to the second wave of the outbreak (Fan & Cheong, 2021).

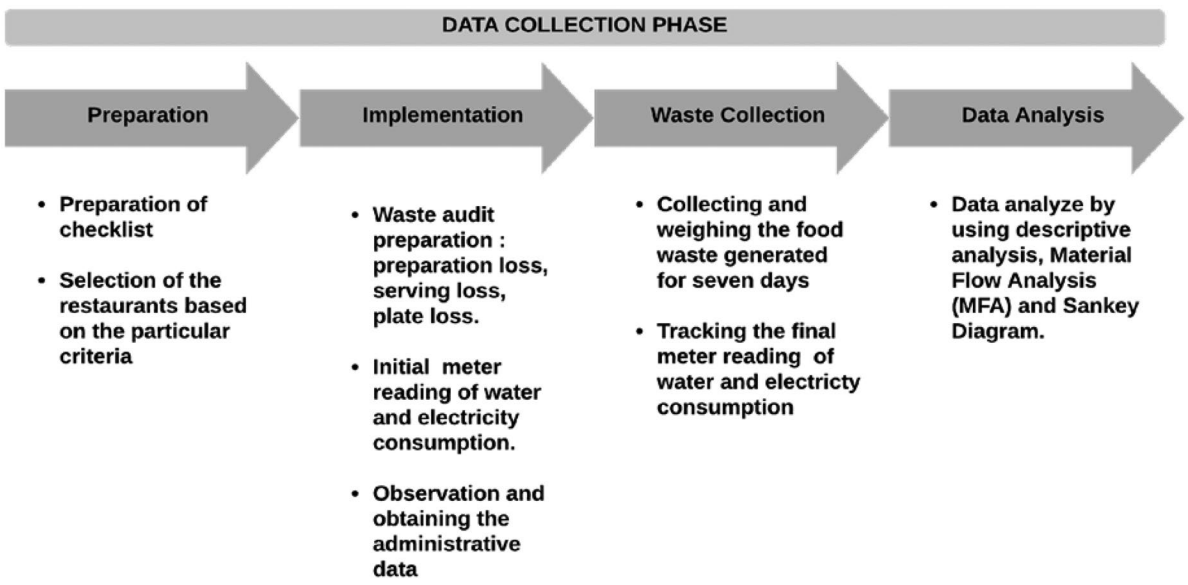

Fig. 1 The data collection phases involved in this study

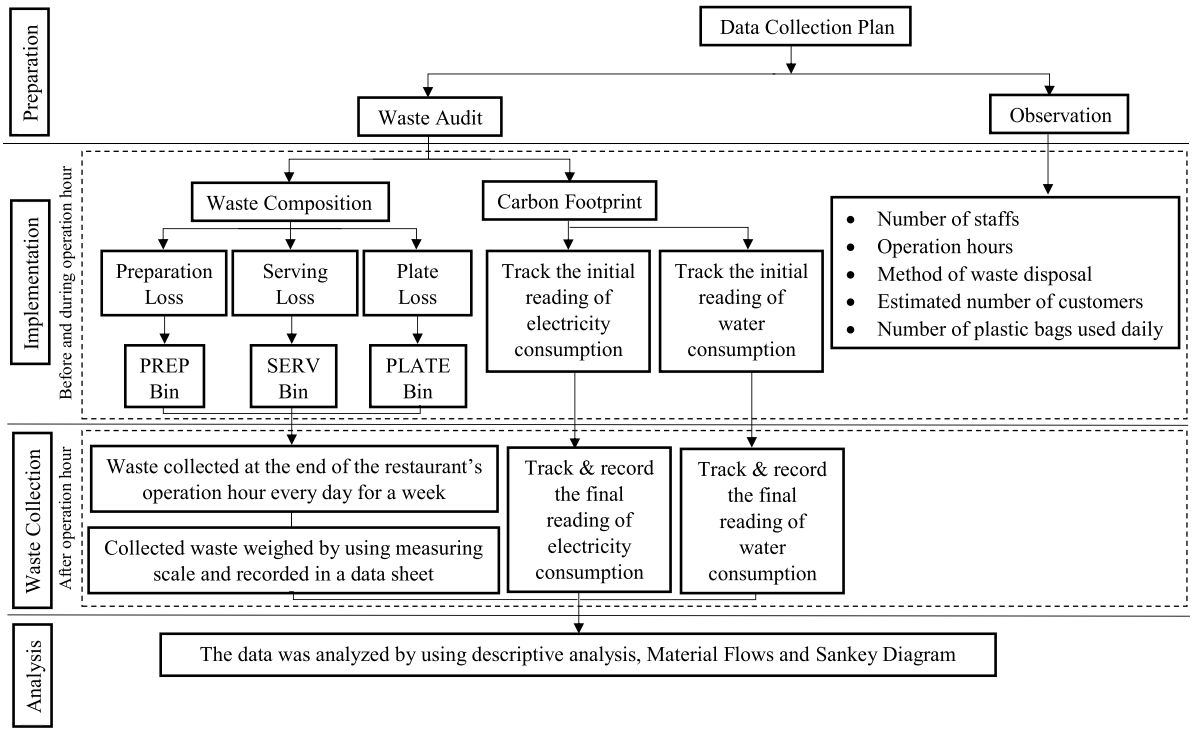

Fig. 2 Flow diagram of the detailed data collection plan. Abbreviations: PREP, preparation loss; SERV, serving loss; PLATE, plate waste

Food loss categories

According to (Engström & Carlsson-Kanyama, 2004), to improve the harmonisation of the acquisition methods, losses can be divided into four sections: storage loss, preparation loss, serving loss, and plate waste. In this study, only three types of losses were measured:

1. Preparation loss (PREP)—Losses that occur during food preparation and cooking, such as fruit and vegetable peels or spoiled food, collected prior to and during cooking time.
2. Serving loss (SERV)—Leftover food from the buffet or serving bowls obtained after service hours.
3. Plate waste (PLATE)—Uneaten food on customers' plates collected after operation hours.

At these selected casual dining restaurants, three separate bins with different labellings were provided to collect food waste related to the preparation, serving, and plate losses. At the same time, visual observations were conducted to identify waste generation factors at the restaurants. The food waste was then collected at the end of the restaurants' operation hours and weighed using a calibrated weighing scale to get an accurate reading.

Data analysis

The proportion of food loss generated from each category was determined by conducting the material flow analysis (MFA) using Sankeymatic.com. Previous studies adopted this method to identify the quantity of material input and output related to food loss in order to create a more sustainable practise of food waste management (Amicarelli et al., 2020; Padeyanda et al., 2016). Using MFA as a tool is supported by (Kasavan et al., 2021), wherein MFA is one of the analyses that can depict the entire flow of materials within complex systems, from input to output. Various studies have used MFA as a tool, such as (Wu et al., 2021), to identify the carbon footprint resulting from the import and export activity of the world regions. Other than that, (Betz et al., 2015) used MFA to identify food and monetary losses. In addition, MFA is also an effective instrument for

Table 1 Emission factors for each activity data

Activity data	Type	Unit	GHG	Emission factor
Electricity	Malaysia (commercial rate)	Kilowatt-hours (kWh)	kg CO2 e	0.10919
Water consumption	Water supply	Cubic meters (m^3)	kg CO2 e	0.344

assessing and evaluating the food waste management of input and output of waste created in the foodservice industry, including casual dining, in terms of both quantity and quality measurements.

Meanwhile, a specific equation was used to calculate the partial carbon footprint of the restaurants using their electricity and water consumption readings (Mekonnen & Hoekstra, 2011). Two main elements were considered in this equation: (i) the activity data (AD), which indicates the process of quantification, and (ii) emission factor (EF), which indicates the amount of carbon released per activity data (AD) unit, as shown Eq. 1 (Malek & Kumarasan, 2019):

$$\textit{Carbon footprint}\ (kgCO_2e) = \textit{Activity data}\ (AD) * \textit{Emission factor}\ (EF) \quad (1)$$

The emission factors (EF) used in this study were based on Table 1, adapted from a previous carbon footprint study conducted at Universiti Teknologi Nasional (a local university) (Malek & Kumarasan, 2019):

Results and discussion

Food waste generation by different loss categories during casual dining restaurants' daily operation

A total of 2186.53 kg of food waste was produced from 15 casual dining restaurants in three different districts of Peninsular Malaysia, with an average of 145.77 kg of food waste generated from each restaurant in a week (Table 2). From this analysis, we observed that preparation loss contributed the most to the food waste generation (1123.2 kg), followed by serving loss (676.83 kg) and plate loss (386.5 kg). The daily weighing-up value for each loss category from all three districts revealed that the highest total food waste generated from preparation loss was during the weekend, whereby Sunday generated the largest quantity, which is 178.3 kg (Table 3). Similarly, for the serving loss category, Sunday was the biggest contributor compared to other days, with a total amount of 109.15 kg of waste generated, followed by Saturday (104.7 kg) and Tuesday (107.6 kg) (Table 4). In contrast, the day that had the largest amount of plate loss was Wednesday, with 63.5 kg of waste produced, followed by Friday (59.3 kg) and Saturday (57.2 kg) (Table 5).

The weekend for Ampang and Jasin consists of Saturday and Sunday, while for Kota Bharu, the weekend is on Friday and Saturday. Considering this time frame, we can see that the waste production at all three locations of the restaurants rose proportionally to the demand for foodservice, which depends on the number of walk-in customers and online orders. People usually enjoy dining out on weekends to unwind and enjoy themselves after a long week. However, some prefer to cook at home due to the safety measures of COVID-19 transmission (Nair, 2020). As stated by (Liu et al., 2020), the COVID-19 virus has mainly triggered the concerns of many due to its morbidity rate and speed of spread. Perhaps, this could be one of the reasons why more food waste was generated during the weekend, whereby the customers that came in

Table 2 Food waste generation by different loss categories

Region of the restaurants	Food loss categories			Total weight (kg $week^{-1}$)
	Preparation loss	Serving loss	Plate loss	
Ampang	598.3	64.3	110.2	772.8
Kota Bharu	136.3	492.43	118.8	747.53
Jasin	388.6	120.1	157.5	666.2
Total	1123.2	676.83	386.5	2186.53

Table 3 Prep loss from casual dining restaurants in three different Malaysian districts

Preparation loss	kg day^{-1}							Total weight (kg week^{-1})
	Day 1 (Sun)	Day 2 (Mon)	Day 3 (Tue)	Day 4 (Wed)	Day 5 (Thu)	Day 6 (Fri)	Day 7 (Sat)	
Ampang	90.6	81.9	87.5	79.3	76.5	93.6	88.9	598.3
Kota Bharu	20.8	21.2	22.7	16.9	12.7	21.7	20.3	136.3
Jasin	66.9	50	52.8	46	53.1	57.4	62.4	388.6
Total	178.3	153.1	163	142.2	142.3	172.7	171.6	1123.2

or ordered online did not meet restaurant owners' estimations for the number of customers.

Material flow analysis (MFA) on the production of food waste in casual dining restaurants

Food waste flow and loss types with higher waste generation were identified using the material flow analysis (MFA) (Fig. 3). From this analysis, preparation loss (51.37%, equals to 1123.2 kg of waste in a week) was the biggest type of food waste generated in all three districts (Ampang, Kota Bharu, and Jasin) during the pandemic, while serving loss (30.95%, equivalent to 676.83 kg of waste) came second and plate loss (17.68%, equals to 386.5 kg of waste) last. Generally, food loss is generated during the process that occurs in casual dining restaurants, such as the pre-serving stage, including storage, peeling, cutting, expiration, cooking, and trimming process before entering the serving and consuming stages, such as on-plate or leftover. The reason behind the lower percentage of plate loss from this analysis was due to the fewer customers that dined in, as most were still anxious to eat out. Meanwhile, the factor contributing to serving loss was that owners expected more customers to come. On the other hand, expired or stale raw materials were one factor of preparation loss, which could be avoided if the owners or managers prepared a detailed kitchen inventory list.

This evaluation was conducted to help restaurant owners or managers take the initiatives to reduce food loss by determining which category was the most significant contributor to food waste generation. From our observation, the preparation loss was a more prominent food waste contributor than the plate loss, indicating that the generation of food loss in the pre-consuming stage was much bigger. Our result is consistent with a previous study conducted within the UK hospitality and foodservice sector (Parfitt et al., 2013). Although some would say that preparation loss is inevitable, restaurant owners and managers can stock up on lesser raw materials to avoid food spoilage, to reduce the amount of waste generated from this category. Plate loss contributed the least to food waste production. From another perspective, some food chain restaurants, especially those serving buffets, charge a penalty fee to customers for their leftovers. Perhaps, the same can be implemented at casual dining restaurants to reduce waste from this category. As for the serving loss category, the restaurants should prepare less food, especially during the weekends when owners expect more customers to come. The restaurant's kitchen can also consider preparing the food by batch if there will be more customers to come.

Regardless, our MFA suffers from the lack of data on the avoidable and unavoidable food waste, which were covered in previous studies (Cakar et al., 2020; Ng et al., 2019), as well as the fate of the food waste

Table 4 Serving loss from casual dining restaurants in three different Malaysian districts

Serving loss	kg day^{-1}							Total weight (kg week^{-1})
	Day 1 (Sun)	Day 2 (Mon)	Day 3 (Tue)	Day 4 (Wed)	Day 5 (Thu)	Day 6 (Fri)	Day 7 (Sat)	
Ampang	4.7	5.8	8.7	8.2	13	11.9	12	64.3
Kota Bharu	82.25	69.85	82.5	59.53	63	64.7	70.6	492.43
Jasin	22.2	14.1	16.4	14.3	17.2	13.8	22.1	120.1
Total	109.15	89.75	107.6	82.03	93.2	90.4	104.7	676.83

Table 5 Plate loss from casual dining restaurants in three different Malaysian districts

Plate loss	kg day^{-1}							Total weight (kg week^{-1})
	Day 1 (Sun)	Day 2 (Mon)	Day 3 (Tue)	Day 4 (Wed)	Day 5 (Thu)	Day 6 (Fri)	Day 7 (Sat)	
Ampang	13.4	14.2	14.5	18.6	12.6	18.2	19	110.2
Kota Bharu	13.9	13.15	15	17.1	15.65	25.6	18.4	118.8
Jasin	21.6	20	29.8	27.8	19.4	19.1	19.8	157.5
Total	48.9	47.35	59.3	63.5	47.65	62.9	57.2	386.5

after, whether it was redistributed, treated or disposed. In fact, food waste from the preparation stage could be used to feed livestock, whereas the surplus food could be redistributed to people in need via collaboration with the local food banks (EU Platform on Food Losses & Food Waste, 2019; Salemdeeb et al., 2017). Moreover, a recent study showed higher environmental and economic losses imposed by animal-based food waste relative to non-animal-based food waste produced by the Daegu (South Korea) households (Adelodun et al., 2021). Perhaps, one of the initiatives that could be considered by the foodservice sector is a transformation towards plant-based diets to diminish resource and environmental losses related to food waste (Niu et al., 2022), where it has been increasingly popular nowadays, especially among the developed nations. In addition, the data from this study is limited to food loss at the foodservice stages of preparation, serving, and consumption only. Food lost at other steps in the food supply chain, including production,

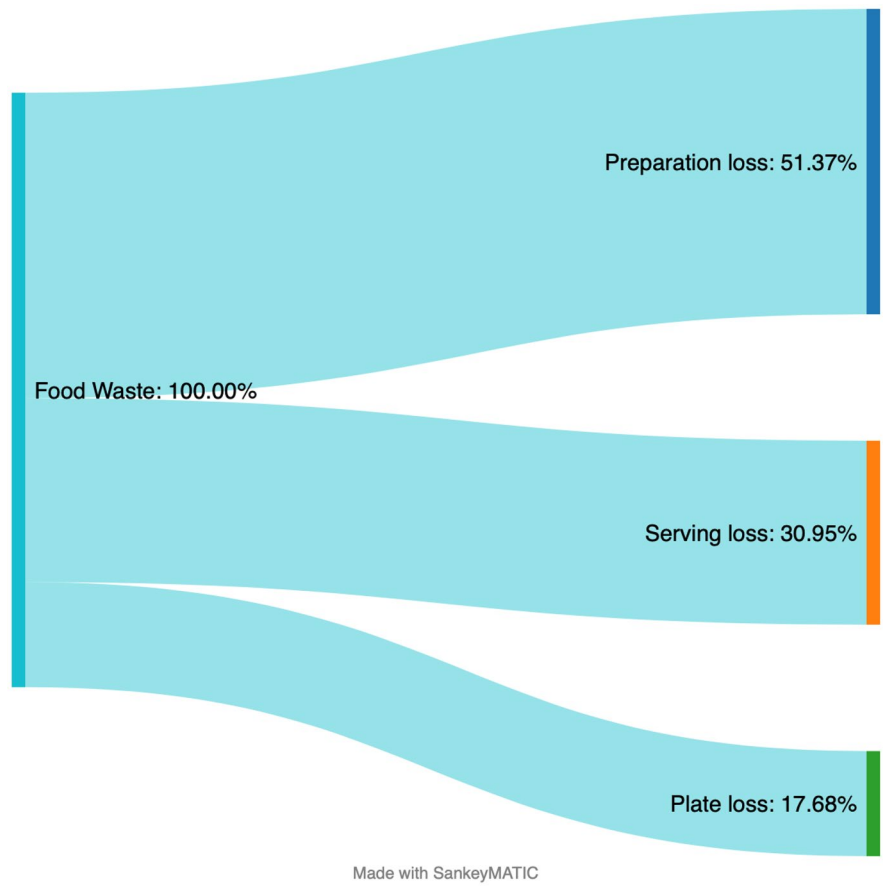

Fig. 3 Material flow analysis of food waste from casual dining restaurants in three different districts of Peninsular Malaysia. This Sankey diagram was generated using Sankeymatic.com

post-harvest processing and storage, packing, distribution, and retailing, were not included in our investigation. In this regard, a multilevel system analysis, which is a material flow analysis at a larger scale comprising the organisational level, in our case, the foodservice establishments, as well as the community and national levels (Ng et al., 2019), will bring greater benefits in directing Malaysia towards a circular economy.

Carbon emission from casual dining restaurants' electricity consumption

The average electricity consumption at casual dining restaurants in Kota Bharu consumed an extensive amount of electricity compared to the other two locations, Ampang and Jasin (Fig. 4). As seen in the graph, Saturday demonstrated a considerable amount of electricity consumption for all three locations in this study, with a total of 88 kWh. On the other hand, Wednesday or Day 4 had the lowest electricity consumption, totalling 70.4 kWh. Meanwhile, the district with the highest total average daily electricity consumption in a week was Kota Bharu (269.8 kWh), followed by Ampang (127 kWh) and Jasin (142.2 kWh) (Table 6).

The carbon emission calculated from the average daily electricity consumption demonstrated that Kota Bharu is the district with the highest carbon footprint throughout the week compared to the other two locations in this study (3.8–4.98 kgCO2e; Fig. 5). Other than that, Kota Bharu and Ampang showed the highest amount of carbon released on Saturday (4.98 kgCO2e and 2.18 kgCO2e, respectively), compared with other days, due to the larger electricity consumption at all casual dining restaurants involved. Interestingly, in Jasin, the carbon footprint released was the highest on Monday (2.49 kgCO2e) and the lowest on Saturday (1.97 kgCO2e). The total carbon footprint produced in a week was the highest in Kota Bharu (29.47 kgCO2e), followed by Jasin (15.54 kgCO2e), and Ampang (13.87 kgCO2e) (Table 6).

From this information, it can be concluded that the food industry, in our case, the casual dining restaurants consumes an extensive amount of energy, which starts from the initial preparation procedure until the final consumption by the customers. Moreover, it has been shown that the energy consumption of the foodservice facilities tripled the amount of that in other types of commercial buildings (PG&E, 2010). The usage of

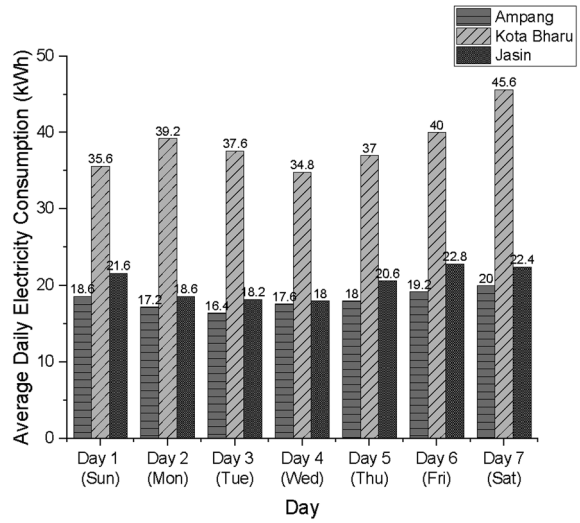

Fig. 4 The average daily electricity consumption of casual dining restaurants in three selected districts of Peninsular Malaysia, reported in units of kilowatt per hour (kWh)

kitchen appliances such as refrigerators, rice cookers, and water heaters may contribute to the total amount of power consumed at the establishment. This is supported by (Mudie et al., 2013), in which refrigerators constitute a significant portion of the energy consumed for food storage. From our observation, most of the selected restaurants in this study used at least one refrigerator and chiller to accommodate and sustain their raw material temperatures, such as vegetables, meat, chicken, fish, and other raw materials. This was also to prevent food spoilage as all the raw materials used are mostly perishable and easy for microorganisms to grow at the 'danger zone' if the temperature range is not maintained (Byrd-Bredbenner et al., 2013). Another possible component of higher electricity consumption is non-efficient electrical appliances (De Grosbois & Fennell, 2015).

Table 6 The total average daily electricity consumption and carbon footprint of casual dining restaurants in three selected districts of Peninsular Malaysia in a week

District	Total average daily electricity consumption (kWh)	Total carbon footprint produced (kgCO2e)
Ampang	127	13.87
Kota Bharu	269.8	29.47
Jasin	142.2	15.54

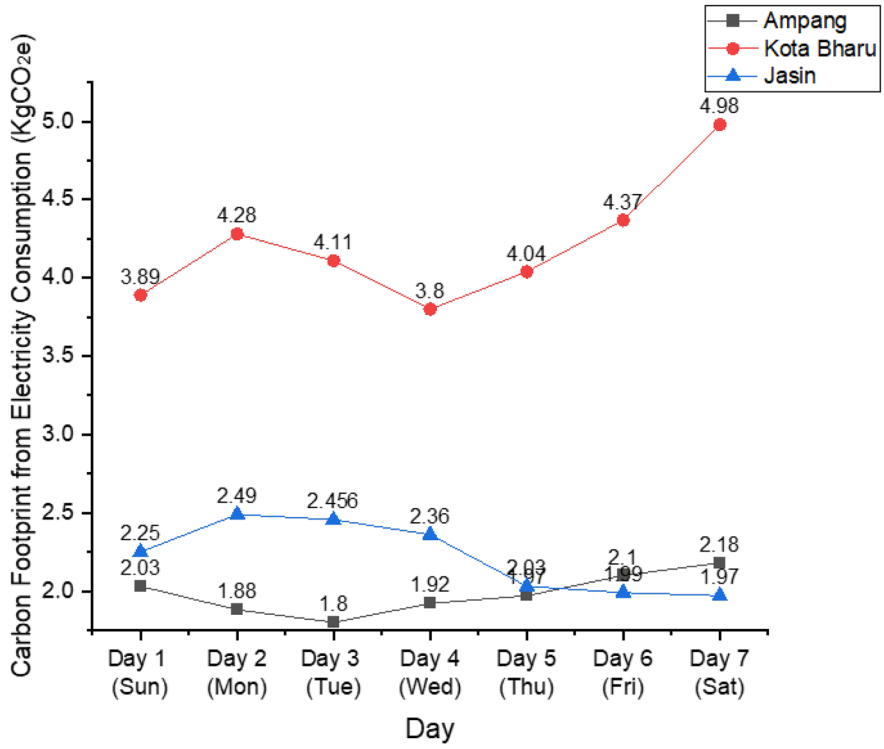

Fig. 5 The average daily carbon footprint produced from electricity consumption of five casual dining restaurants at three different locations

Global warming has been a hot topic for quite a while, in which the most significant contributors that we know of are industrialisation, deforestation, oil drilling, and transport and vehicles (Berry, 2021). Meanwhile, we neglect that the basic needs of our life, such as food (which involves farming and fishing) and clothes (which represents consumerism), share the same amount of responsibility in this phenomenon. Importantly, it has been shown that the food chain under the food industry sector is also a greenhouse gases (GHGs) emitter in which every stage of its life cycle, from agriculture and its inputs to manufacturing, distribution, refrigeration, preparation, serving, and also to the customer plate, contributes a certain percentage to the GHG emissions (Garnett, 2011). Nonetheless, there is an emerging concept of circular economy from which the food-service industry could benefit, where energy, materials, and labour are preserved via a closed loop system incorporating the 4 R's, which are reduce, reuse, recycle, and remove, to eliminate waste and emissions (Alsarhan et al., 2021). Recently, food waste treatments, such as composting and anaerobic digestion, were shown to be able to recover resources and energy, while waste avoidance provides far greater environmental and economic sustainability (Marrucci et al., 2020; Slorach et al., 2019). Other than that, urban farming and local production of food could also help in climate change mitigation (Paiho et al., 2021), apart from utilising water- and energy-efficient appliances (Geglio et al., 2021).

Carbon emission from casual dining restaurants' water consumption

The daily average water consumption (m^3) and its related carbon footprint of casual dining restaurants in three different Malaysian districts were depicted in Figs. 6 and 7, respectively. Water consumption at the three locations of casual dining restaurants peaked on Thursday at an average of 15.23 m^3, whereby Kota Bharu contributed the highest water consumption compared to the other two locations (Fig. 6). Our data also demonstrated that Kota Bharu monopolised the total water consumption in a week, contributing about 60% from all three districts (Table 7).

On the other hand, the data for the amount of carbon footprint from the average daily water consumption revealed that Kota Bharu was the top generator of carbon footprint in comparison to Jasin and Ampang

in 1 week (Fig. 7; Table 7). Besides, it was shown that Saturday generated a considerable amount of carbon footprint, with a total of 5.09 kgCO2e (Fig. 7). Meanwhile, the days that produced the least carbon footprint were Wednesday and Tuesday, which were 4.36 kgCO2e and 4.65 kgCO2e, respectively.

While casual dining restaurants from Jasin (a suburban area) had a moderate amount of water usage during their operating hours, similar to those restaurants in Ampang (an urban area), casual dining restaurants in Kota Bharu showed the opposite where their water consumption in a week doubled the amount of those in the urban areas. We also noticed that when the quantity of food loss increased, the volume of water usage also increased, consequently producing a higher amount of carbon footprint from the restaurants. This finding was supported by (Kummu et al., 2012), whereby food loss and food waste in the foodservice industry participate in 24% of freshwater consumption globally. Additionally, some tasks in restaurants use a lot of water, for instance, cleaning the raw materials, preparing drinks, dishwashing, hand washing for the customers, lavatory usage, sanitation purposes as, well as ventilation purposes such as air humidifiers and diffusers. This is supported by previous data analysed by the US Environmental Protection Agency, showing that 52% of the end uses of water in restaurants was attributable to the kitchen and dishwashing (EPA, 2012). Other than that, water is not

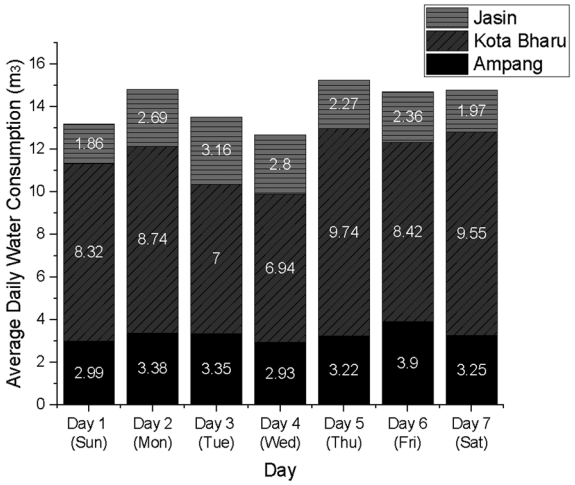

Fig. 6 The average daily water consumption of five casual dining restaurants at three different locations. The water consumption data was portrayed in the cubic meter (m^3) unit

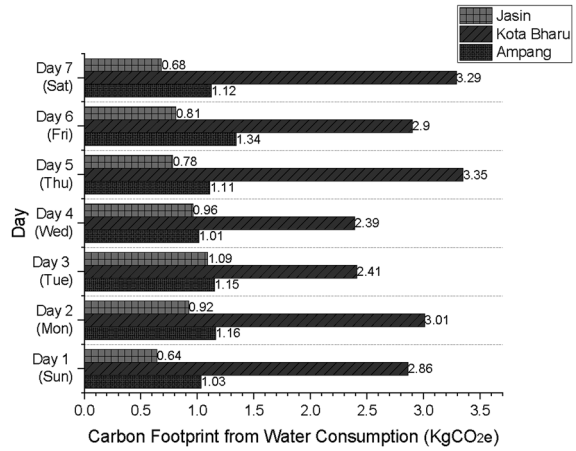

Fig. 7 The average daily carbon footprint produced from water consumption of five casual dining restaurants at three different locations

only required for food production but is also increasingly utilised in waste valorisation (Subramanian et al., 2021). Besides, the number of customers per day also plays a role in the total water consumption, consequently, the amount of carbon released as well.

Nevertheless, further research is necessary to better understand the environmental impacts of the daily operations of food establishments in Malaysia, which incorporates GHG emissions from ingredient and beverage production, as well as transportation, like in one recent study (Falciano et al., 2022). Studies at a larger scale will also help provide enough information for the implementation of a circular economy in the foodservice industry of Malaysia. As of the current study, the food waste and carbon footprint data are expected to augment as restaurants are allowed to operate back to normal now, in line with the lifting of COVID-19 restrictions. Hence, the efforts in mitigating food waste and the associated carbon and water footprints in the foodservice industry shall be doubled.

Table 7 The total average daily water consumption and its related carbon footprint of casual dining restaurants in three selected districts of Peninsular Malaysia in a week

District	Total average daily water consumption (m^3)	Total carbon footprint produced (kgCO2e)
Ampang	23.02	7.92
Kota Bharu	58.71	20.21
Jasin	17.11	5.88

Conclusions

Food waste and food loss generation from the foodservice industry has become an enormous threat globally. This is because most of the waste dumped generates a massive amount of greenhouse gases that negatively affect the environment, yet, the impacts of the COVID-19 pandemic on food waste and the carbon footprint of the foodservice sector are not fully elucidated. The incorporation of MFA in this study revealed that the top contributor to food waste generation at casual dining restaurants from three different districts in Peninsular Malaysia was preparation loss, followed by serving loss and customers' plate loss. The former loss was caused by the slow-moving food inventory in the restaurants' kitchens hence the higher rate of food spoilage, whereas the number of walk-in customers greatly influenced the other two-loss categories. Importantly, the total carbon footprint from electricity and water consumption of casual dining restaurants in Kota Bharu doubled the amount of those in Ampang and Jasin, translating to an overpreparation of food, as reflected in the amount of their serving loss. These findings highlight the importance of sustainable knowledge and practices among the managers and employees of the restaurants in order to reduce food waste generation and carbon footprint to save the environment as well as our precious resources.

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Availability of data and materials The datasets collected and used during the current study are available on reasonable request.

Declarations

Ethics approval Not applicable.

Ethical responsibilities of authors All authors have read, understood, and have complied as applicable with the statement on 'Ethical responsibilities of Authors' as found in the Instructions for Authors.

Consent to participate Not applicable.

Conflict of interest The authors declare no competing interests.

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