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ENVIRONMENTAL ASSESSMENT ON DAILY OPERATION OF SELECTED FOOD SERVICE ESTABLISHMENT IN NORTHERN REGION OF MALAYSIA

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Abstract: Food waste is the second-highest source of solid waste in Malaysia. It accounts for about 32% of the total volume of waste generated in the country. Western food restaurants and Indian Muslim (also known as *Mamak*) restaurants in Northern Region, Malaysia are fast-growing food establishments and have become common among Malaysians of different races. Thus, this study aimed to identify the waste generation, carbon footprint and water footprint during the daily operation of these two types of food establishment. The waste from the food establishment was classified and measured into three categories: Preparation loss (PREP), serving loss (SERV) and customers' plate loss (PLATE). The Material Flow Analysis (MFA) was used to exhibit the amounts of food waste generated and the factors that most significantly contributed to the amount of food waste during daily operations. The findings of this study presented that PLATE waste contributed to most of the food waste with 62.9% (Western) and 54.9% (Indian Muslim), compared to PREP losses generated which were 37.1% (Western) and 45.1% (Indian Muslim). The weekly average electricity consumption was 17.3 kWh (Western) and 267.8 kWh (Indian Muslim). Besides, the total weekly carbon footprint was 17.6 $kgCO_2e$ (Western) and 29.24 $kgCO_2e$ (Indian Muslim). Meanwhile, the total average water consumptions were 21.82 m^3 (Western) and 38.2 m^3 (Indian Muslim) and the total carbon footprint emission per week was 7.5 $kgCO_2e$ (Western) and 13.19 $kgCO_2e$ (Indian Muslim). The management of the food establishment may be able to recognise the areas for improvement in reducing food waste generation and carbon footprint from their daily operations.

Keywords: Material Flow Analysis (MFA), food waste, carbon footprint.

Introduction

Food waste refers to any waste product arising from the different phases in food production, processing, distribution and final consumption. Food waste may also be categorised as any food discharged in the hospitality sector as part of the food service process (Pirani & Arafat, 2016). Rapid urbanisation and industrialisation in Malaysia have modified solid waste generation which has drastically increased from 9.0 million tonnes (Mt) in the year 2000, 10.9 million tonnes (Mt) in the year 2010 and 15.6 million tonnes (Mt) in the year 2020 while the rate of recycling is estimated at only 10% from solid waste generation (Samah *et al*., 2015). The waste composition may be contributed to several factors: Economic growth, culture, geography, energy sources and climate.

Food waste production is accountable for a considerable amount of greenhouse gas emissions in the environment (Chapagain *et al*., 2013). A large amount of food waste can harm the environment such as greenhouse gases (GHGs), methane and carbon dioxide that are emitted from the decomposition of food waste in landfills and imposed on water and carbon footprint. Air pollutants such as odorous gases, heavy metals and particulate matter may be the outcome of waste disposal and treatment and have become one of the causes of air pollution (Hezhong *et al*., 2013). The global food services industry is involved in food consumption and

waste generation. Pirani and Arafat (2016) claimed that food service is the sector from which food waste is most generated other than households. Therefore, the mitigation focus is on the large global food division provided through food services in restaurants, fast food chains, bars, cafes, cafeterias, canteens, dining rooms and event catering. Historically, the hospitality and food service industry has had a significant environmental impact due to energy and water consumption and the consumption of consumable goods. Reducing food waste and resource consumption is crucial to the food service industry's sustainability challenge (Martin-Rios *et al*., 2018; Han, 2021). Dagiliūtė and Musteikytė (2019) also reported that the cause of the increased generation of food waste in the food service industry is the lifestyle of eating out.

Malaysia is eminent as a food paradise for its diversity of dishes and unique food culture. Unfortunately, the distinct food culture has also devolved into a waste culture (Ghafar, 2017). The growing population and economy in Malaysia have led to high demand for the food service sector such as western food restaurants, casual dining restaurants, steamboat restaurants and Asian food restaurants. Some fast-food restaurants and cafes follow the latest consumerism trends. The expansion in the operations and population of this hospitality sector leads to an increase in waste production from the food preparations process, the remaining feast portion and the serving of unconsumed food (Padeyanda *et al*., 2016).

This study was mainly conducted in the Northern Region of Malaysia, a part of Peninsular Malaysia consisting of four states: Perlis, Kedah, Penang and Perak, offering competitive advantages and expansion for the shared national economic growth. Two types of popular food service with a family restaurant concept, Western food restaurants and Indian Muslim food restaurants (also casually known as *Mamak*) were selected from Kedah and northern Perak. This study aimed to determine the environmental assessment of the daily operations of each type of food restaurant using Material Flow Analysis (MFA). Material Flow Analysis is a systematic assessment to determine the flow process of waste produced by measuring the amount of food wasted at different phases in restaurants within a specific period. In addition, this study also determined the carbon footprint from electricity and water consumption to further understand the impact on the environment.

Methodology

Determination of Food Waste

A checklist has been prepared to include the number of staff, operation hours, method of waste disposal, estimated number of customers, waste generation and electricity and water consumption (Appendix A). According to Felder (2001), a solid waste audit is designed to determine the characteristics of solid waste generation and guide waste reduction. The food losses were classified into preparation losses (PREP), serving losses (SERV) and plate waste (PLATE) according to the method by Betz *et al*. (2015).

Three separate bins with different colour codes were made available for five Indian Muslim and Western food restaurants to collect food waste. Onsite weighing of food waste was conducted and recorded according to the three categories of losses using a calibrated weighing scale. Then, the initial and the final reading of electricity and water consumption of the day were tracked and recorded.

Material Flow Analysis (MFA) is used to determine the flow process of the waste produced at the different types of food services. It can determine the stages of the food process that causes the highest food waste generation. Each food waste category was computed for a one-week study period. The total quantity of food waste generated in each category was summed and reported as a percentage of the total weight of food waste. The carbon footprint from electricity and water consumption in the restaurants was calculated using specific formulas according to the method by Mekonnen and Hoekstra (2011).

Quantification of Carbon Footprint

Carbon footprint is the total amount of carbon dioxide (CO_2) and the emission of greenhouse gases over the life cycle, either directly or indirectly from the routine of human activity. Two parameters were needed to quantify carbon emissions from an operation or process. The first is activity data (AD) which indicates the process quantification. Unit measurement data is allocated to the operation data of the organisation. The emission factor (EF) is the other parameter required, which indicates how much AD unit emits CO_2 emissions. According to the methodology by Malek and Kumarasan (2019), for the calculation of the carbon footprint of the process or consumption of goods, the main equation was developed as shown in (1):

Carbon footprint ($kgCO_2e$)
= Activity Data (AD) * Emission Factor (EF) (1)

The emission data is important to obtain the total carbon emissions generated within the food service establishment. The emission factors for each activity data obtained were based on direct measurements of processes or publicly available data such as GHGs conversion factors from the United Kingdom Department for the Environment, Food and Rural Affects (Defra) or the Department of Energy and Climate Change (DECC) (Hill, 2011). After that, the emission factor for electricity activity data based on Malaysia's commercial rate is 0.10919 $kgCO_2e$/kWh while the emission factor for water consumption is 0.344 $kgCO_2e/m^3$.

Result and Discussion

Food Waste Generation by Different Loss Categories on Daily Operation

Food waste was classified into three categories which are preparation loss (PREP), serving loss (SERV) and customer plate waste (PLATE). However, only data on PREP loss and PLATE loss were collected while SERV was not applicable for this study because there was no food discarded from the serving loss within the time the food waste audit was performed. Food waste generation from preparation loss (PREP) and plate loss (PLATE) at western and Indian Muslim restaurants are shown in Table 1.

The greatest amount of PREP loss generated was 78.1 kg by an Indian Muslim food restaurant compared to the Western food restaurant PREP loss that only produced 46.0 kg. The amount of

Table 1: Food waste generation from preparation loss

PREP Loss at Restaurant	Day/kg							Average Total Weight (week/kg)
	WD 1	WD 2	WD 3	WD 4	WD 5	WE 1	WE 2	
Western	6.2	5.8	5.6	6.0	6.4	8.2	7.8	46.0
Indian Muslim	10.5	10.2	11.1	10.6	11.4	12.6	11.7	78.1
Total (day/kg)	16.7	16.0	16.7	16.6	17.8	20.8	19.5	124.1

PLATE Loss at Restaurant	Day/kg							Average Total Weight (week/kg)
	WD 1	WD 2	WD 3	WD 4	WD 5	WE 1	WE 2	
Western	11.6	10.8	10.0	10.4	10.6	12.6	12.4	78.4
Indian Muslim	12.2	12.8	13.0	14.0	13.7	15.1	14.7	95.5
Total (day/kg)	23.8	23.6	23.0	24.4	24.3	27.7	27.1	173.9

Note: WD=Weekday, WE=Weekend

food waste generated varies depending on the cooking and serving method as Western food restaurants may cook ala carte as per customer's order while Indian Muslim restaurants have buffet selections apart from the ala carte. Certain services in the food service industry that provide abundant food such as buffets also cause food waste (Ishangulyyev, 2019). If food operators do not store raw materials properly before cooking, this practice may also produce food waste due to food spoilage.

The PREP loss generated on weekends is higher than on weekdays, totalling 20.8 kg (WE 1) and 19.5 kg (WE 2) for both restaurants. However, Indian Muslim food restaurants generated more PREP waste on the weekend, which was 12.6 kg (WE 1) and 11.7 kg (WE 2) while Western food restaurants only generated 8.2 kg (WE 1) and 7.8 kg (WE 2). Weekends were the major days that produced PREP loss, indicating that more customers frequented the restaurants during weekends for leisure and family/friend gatherings as during weekdays, they may usually do takeaways.

Besides, for PLATE loss, the greatest amount of food waste generated was 95.5 kg from Indian Muslim restaurants compared with 78.4 kg from Western food restaurants. Plate waste contains scrapings from the plates of service guests which for some dishes include unavoidable food waste or leftovers such as peels and bones on the buffet after the lunch serving (Papargyropoulou *et al*., 2019). The amount of food waste generated might be linked to the variety of foods available at Western and Indian Muslim food restaurants due to the operation hour and trend of customers' visitation on each day of the week.

From the observation during data collection, the amount of PLATE loss generated on weekends is higher than on weekdays due to customer visitations. This result indicates that WE 1 (Friday and Saturday) was the highest consumers use food restaurant services due to weekend operation after working for the whole week. In addition, many customers choose to dine in at food restaurants due to their friendly service, as some of the waiters even can remember the repeat customers' favourite menu when dining in their restaurant (Ibrahim *et al*., 2017).

Material Flow Analysis (MFA) on Food Waste Generation

The study then applied material flow analysis (MFA) to identify the food waste from different food loss categories in the two types of food restaurants. MFA considers the waste metabolic systems where waste and substance flows are monitored for waste management and examining all inputs and outputs in the system (Allesh & Brunner, 2018).

Material Flow Analysis (MFA) diagram was performed by using SankeyMATIC (BETA) software to visualise the magnitude of the material flows taking place within Western food restaurants and Indian Muslim restaurants. The results were presented in percentage and the form of a Sankey diagram as in Figure 1.

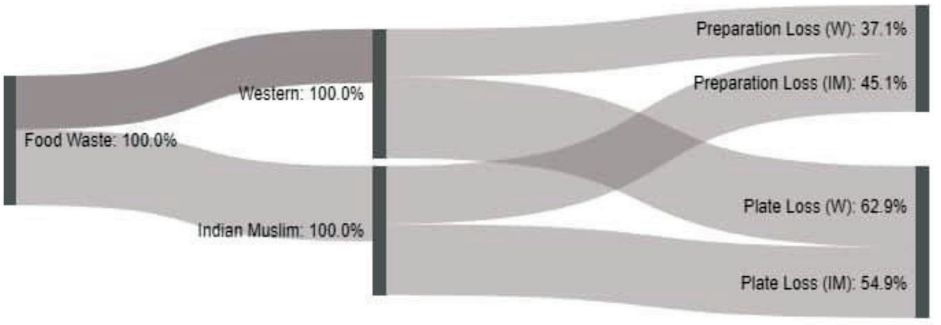


Figure 1: MFA on daily operation of food services establishments

It is clearly shown that customer plate waste (PLATE) from both types of food restaurants tends to be more significant compared to preparation waste (PREP). Material flow analysis (MFA) on daily operations of Western food restaurants illustrates that food waste contributes to preparation loss and customers' plate waste which are 37.1% and 62.9%, respectively. As for daily operations of Indian Muslim food restaurants, it is illustrated that food waste contributes to preparation loss and plate waste at 45.1% and 54.91%, respectively. This result indicates that food waste at Indian Muslim food restaurants, with 45.1% contributing to preparation loss is higher than Western food restaurants at 37.1%. However, plate waste results indicate that food waste contributes to this loss at Western food restaurants 62.9% higher than Indian Muslim food restaurants at 54.9%. Thus, the result indicates that plate waste for both food restaurants contributed more to food waste compared to preparation loss.

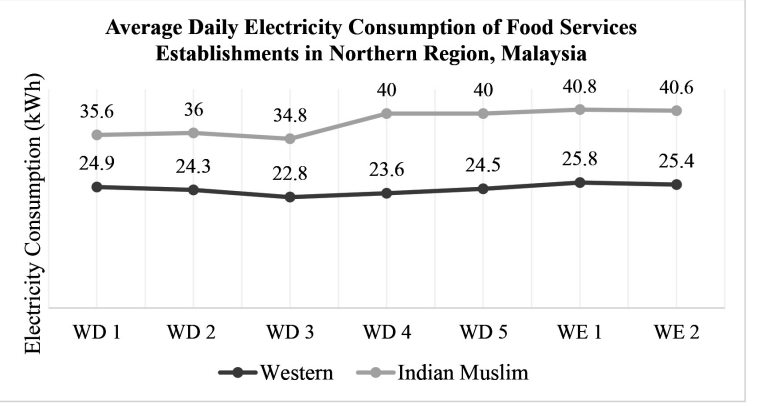
In this study, PLATE waste is an important category, emphasising that customers are one of the key parts that should be focused on in reducing food waste. The PLATE loss is generally related to the consumer's attitude and behaviours (Drewitt, 2013). PLATE loss also shows over half the percentage of total waste generated as customers leftovers on their plates as they could not finish up the food and ultimately ended up in bins. Preparation losses generally consist of peeling vegetables, eggshells and off-cuts from preparing and cooking the menu items. Betz *et al*. (2015) mentioned that SERV loss specifies the food left from the buffet and serving bowl. There was no food waste from the serving category (SERV) in both type of food restaurants as Western food restaurants cook to customer demand and Indian Muslim restaurants give extra food to their staff. The material flow analysis approach is useful for putting the quantity of food waste produced in context and fully understanding the extent of the food waste problem.

Carbon Footprint from Electricity Consumption

This study intended to estimate the carbon footprint caused by the operation of western food restaurants and Indian Muslim restaurants. The daily average electricity consumption from food restaurants in the Northern Region, Malaysia is illustrated in Figure 2.

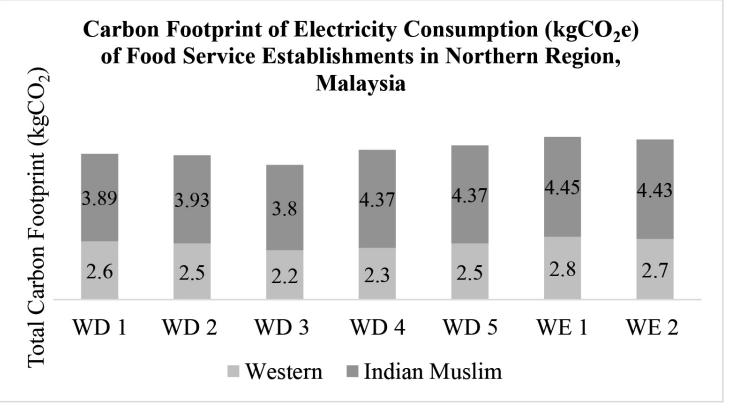
The highest electricity consumption can be seen on weekends for both types of restaurants which are on WE 1 with 25.8 kWh (Western) and 40.8 kWh (Indian Muslim). The results of carbon footprint emissions for electricity usage for food restaurants in the Northern Region were then charted in Figure 3.

The electricity used during the restaurant's operation such as for lighting, ventilation, cooking processes and powered cleaning devices



Note: WD=Weekday, WE=Weekend

Figure 2: Average daily electricity consumption of food service establishments



Note: WD=Weekday, WE=Weekend

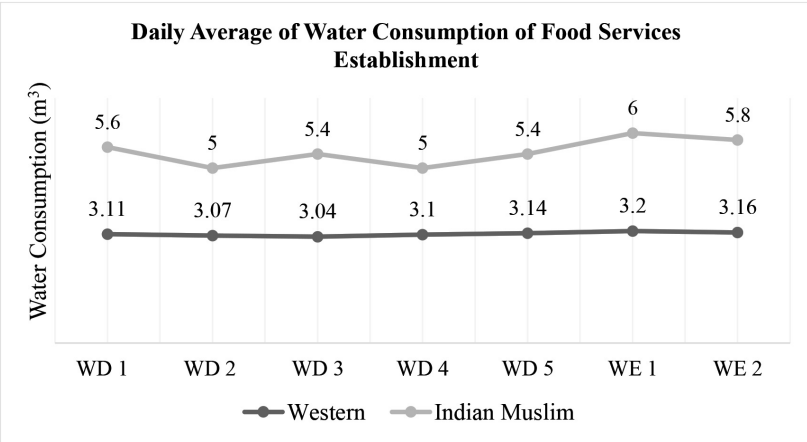
Figure 3: Carbon footprint of electricity consumption of food service establishments

has contributed to the carbon footprint. The lowest contribution was 3.80 $kgCO_2e$ (WD 3) on a weekday, probably because the number of patrons during weekdays is relatively less than at weekends. The kitchen area used electrical appliances such as a rice cooker, flour kneading machine, spice milling machine and other kitchen aid appliances. The energy consumption from kitchen appliances makes up the carbon footprint (Paillat, 2011; Styles *et al*., 2017). Food restaurants consume electricity from their refrigerators and freezers since they have a lot of frozen foods to prevent the spoilage of the raw materials.

Moreover, the refrigerator must be switched on for 24 hours, including during non-operating hours. The energy used for the reach-in refrigerators and freezers consume more electricity and release high carbon emission (Paillat, 2011). The carbon dioxide emission keeps growing due to the demanding uses of electronic equipment such as blenders, refrigerators and air conditioners (Upadhyay & Vadam, 2015).

Carbon Footprint from Water Consumption

The daily average water consumption of the two type of food restaurants is illustrated in Figure 4.



Note: WD=Weekday, WE=Weekend

Figure 4: Daily average of water consumption in food services establishments

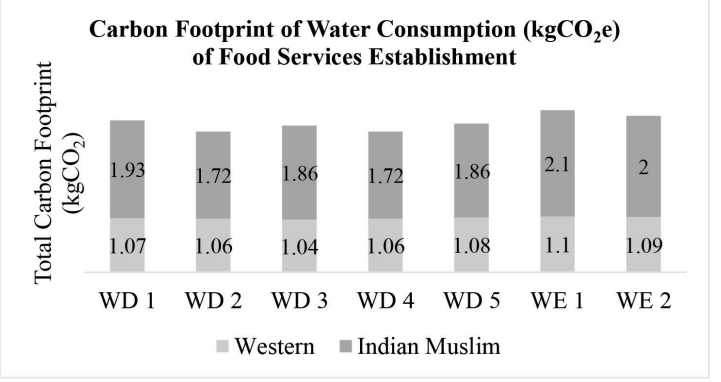
The highest water used for daily operations in both food restaurants is on WE 1, with 3.2 m^3 (Western) and 6 m^3 (Indian Muslim). From the data obtained, the calculation of carbon footprint from water consumption was performed using Equation 1. The results were then presented in Figure 5.

The most water-demanding processes occurring in the kitchens were food preparation and dishwashing. Water consumption in kitchens is dominated by dishwashing as it needs to be cleaned up after every meal (VanSchenkhof, 2011). Choosing an efficient and appropriately sized dishwasher can cut water and energy consumption for dishwashing by more than half compared to washing by hand (Styles *et al*., 2017) and is an important component of best environmental management practices in kitchens. In addition, using soap and detergent for hygiene is important and therefore requires more water and more water, especially to remove oily dirt and soap residue and for personal hygiene (Chan, 2013). Staff training is essential for reducing water consumption in kitchens. Avoiding continuously flowing water to thaw food is one example of a kitchen action that can significantly reduce water consumption. Small changes in food preparation can result in significant reductions in water consumption.

The food service industry greatly strains the environment and demands more natural resources. We conclude that the direct environmental impacts of the food service industries (e.g., energy and water use, solid waste generation) must be recognised and addressed. This study provides the opportunity to test those variables and the industry must be quick to adapt to the technological and behavioural changes and gradually become more "green". Recycling, reusing grey water, preventing waste, reducing energy consumption and lowering carbon footprints are all policies and practices that could be implemented.

Conclusion

Food waste generation and the ecological footprint of the food service industry could cause impacts that could lead to economic, environmental and health problems. Environmental assessment on daily operations of Western and Indian Muslim food restaurants in the booming Northern Region of Malaysia was evaluated and their impacts on the environment were assessed. The most food waste generation was from the consumers' plate waste compared to preparation waste. This study may provide a Carbon footprint because electricity and water consumption were higher on weekends due to the number of patrons. Findings from this study will help food service management to recognise the areas for improvement in reducing their food waste generation and carbon footprint.



Note: WD=Weekday, WE=Weekend

Figure 5: Carbon footprint of water consumption in foodservice establishment

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Appendix A: Waste Audit Checklist

CHECKLIST FOR WASTE AUDIT

Type of food establishment: …….

Part A: Administrative Data	
Operation hours:	
Number of staffs:	
Estimated daily number of customers:	
Is on-site waste composting available?	Yes ☐ No ☐

Part B: Daily Electricity and Water Consumption

A) Daily Electricity Consumption

Day	**Initial Meter Reading (A) (kWh)**	**Upon Closure Meter Reading (B) (kWh)**	**Actual Consumption (B-A) (kWh)**
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Total Weekly Electricity Consumption			

B) Daily Water Consumption

Day	Initial Meter Reading (A) (litres)	Upon Closure Meter Reading (B) (litres)	Actual Consumption (B-A) (litres)
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Total Weekly Water Consumption			

Name of food establishment: …… Date of Audit: ……

Part C: Onsite Food Waste Audit Data

Losses Category	Day/kg							Total Weight (week)/kg
	1	2	3	4	5	6	7	
Preparation loss								
Serving loss								
Customer loss								