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Research Article

Nationwide Household Food Waste Generation Rates in Rural and Urban Settings: Evidence in Thailand

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Abstract

To achieve sustainable development goals, addressing food waste requires evidence-based solutions grounded in a nuanced understanding of waste generation rates and the factors influencing them. This study explores the intricate dynamics of food waste generation in Thai households, encompassing both liquid and solid waste streams. Empirical data were collected from 2,700 diverse households across urban and rural areas over a four-week period. The study revealed an average food waste generation rate of 0.332±0.003 kg per capita per day when liquids were included and 0.228± 0.002 kg per capita per day when liquids were excluded. Surprisingly, rural households generated more food waste than urban households did, likely due to differences in meal preparation and consumption habits. The analysis also revealed a significant negative correlation between household income and food waste in some rural areas, suggesting that income alone does not drive waste behavior. Additionally, a positive correlation between household income and food waste generation rates was observed, underscoring the complex interplay between economic factors and waste generation behaviors. The implications of this research extend beyond Thailand, providing valuable insights into global trends in urban and rural food waste. This study contributes essential knowledge for developing sustainable waste management practices and serves as a benchmark for other regions. Furthermore, the derived food waste generation rates offer predictive tools for estimating future waste volumes, aiding policymakers in targeted interventions and enhancing the efficiency of waste management strategies.

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Introduction

Rising consumption rates, economic growth, and population increases significantly contribute to the escalating trend in waste generation. In 2020, an estimated 2.24 billion tons of solid waste were produced worldwide, with an average value of 0.79 kg per person per day. Projections indicate that annual waste generation may surge by 73%, reaching 3.88 billion tones by 2050, driven by population expansion and urbanization [1]. Food waste, alongside organic waste, accounts for approximately 44% of municipal solid waste [2]. The phenomenon of food loss and waste (FLW) poses a substantial challenge within global food systems, as it threatens food security, safety, economic stability, and environmental sustainability. Although precise estimates of FLW are lacking, Food and Agriculture Organization [3] suggested that it constitutes approximately 30% of the food consumed globally, equating to approximately 1.3 billion tons per year. Effective management of food waste is critical for mitigating climate change, as greenhouse gases are emitted during food production and distribution, with methane being released during the decomposition of food waste. In low- and middle-income countries, food waste and organic matter represent nearly 50% of municipal waste. However, data on food waste in developing countries

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remain limited. While some studies have quantified food waste and supply chains in various nations, including China [4], Iran [5], and Vietnam [6–7], research focusing on food waste generation at the consumption level is still in its early stages in these contexts.

In Thailand, the generation of municipal solid waste has steadily increased over the past decade. Between 2009 and 2019, waste volumes rose by more than 18%, which was attributed to the expansion of urban communities, a shift from agricultural lifestyles to urban lifestyles, and increased per capita consumption [8]. The reported amount of municipal solid waste generated in Thailand in 2019 was 1.15 kg per capita per day [9]. Notably, estimates suggest that organic waste accounted for 64.52% of total municipal waste in 2004 [10], and a 2019 study indicated that food waste accounted for 33–54% of total solid waste in four major Thai cities [11]. However, these figures may not accurately reflect the current status of food waste in the study area, as quantitative data on the proportion of food waste generated at the source are lacking. Thus, primary data on food waste generation at the household level have yet to be comprehensively evaluated.

The United Nations Development Programme (UNDP) has identified food waste as a key target under Sustainable Development Goal 12.3, aiming for a 50% reduction in food waste from global distribution and consumption by 2030. Accurate data on waste generation rates are crucial for developing effective waste management strategies and implementing relevant policies. Previous studies have investigated food waste generation across various sectors, including restaurants in China [12], the hospitality industry in Malaysia and the United Arab Emirates [13–14], airports in Hong Kong [15], and flight catering services in Thailand [16], to understand the rate of total food waste. Food loss and waste represent critical social, economic, and environmental issues, with direct and indirect implications for food security [17]. Numerous international studies have examined food waste generation within households, considering factors such as food security [17], the impact of the COVID-19 pandemic [18–20], sociodemographic characteristics [21], greenhouse gas assessment [22], food waste behaviors [23–25], and policy implementation [26]. Despite Thailand's implementation of food waste reduction initiatives, food waste generation in modern households remains relatively high, particularly in urban areas where increased consumption and convenience-oriented lifestyles contribute to food wastage. A study by the Thailand Development Research Institute [27] indicated that household food waste accounted for approximately 64% of total municipal solid waste, with no significant reduction in recent years. Similarly, reports from the Pollution Control Department (PCD) [28] highlight that despite policy efforts, per capita food waste generation has remained stable, particularly in metropolitan areas.

The main challenges in mitigating food waste in Thailand include a lack of accurate and systematic records on waste generation, insufficient knowledge regarding food waste management, inadequate infrastructure, and a lack of incentives for food waste separation. Current estimates of food waste in Thailand are derived primarily from local government assessments. The country is implementing plans and policies aimed at reducing food loss and waste on the basis of limited information across the food supply chain and a distinct absence of empirical data on actual food waste volumes generated by households. To align with international efforts and effectively minimize food loss and waste, Thailand must establish a comprehensive understanding of its current food waste landscape, but empirical data remain insufficient.

There is still a high need for a dataset and research on food waste generation and management. This research is distinctive in that it measures household food waste generation and uses identical data collection procedures on the same date and duration across all regions in Thailand. This study evaluated household food-waste generation rates by collecting data directly from the source at each household and collecting data over 28 days. This study also focuses on Thai food consumption behavior, as Thai foods and ingredients are highly diverse. Quantifying food waste in both liquid and solid portions may help develop appropriate food waste management strategies and better identify alternative technologies to manage food waste in Thailand. This research conducts an experiment at the national level with a total of 2,700 households participating as primary sources of waste generation. Additionally, factors that may affect food waste generation are investigated. As a result, this study provides ground-level insight into trends in food waste generation in urban and rural communities in Thailand.

Materials and methods

There are 2 major approaches for assessing food waste generation rates. (1) Methods that collect primary data to measure waste from waste-generating sources, such as kitchen diaries [29–30], or types of sources [31–32]. (2) Methods that collect secondary data from questionnaire surveys [33] or literature reviews based on waste statistics from public authorities [34–36]. This research applied the method of collecting primary data directly from households to estimate the waste generation rate at the source.

1) Experimental design and data collection

This study gathered food waste data from 2,700 households over a continuous and uninterrupted 28-day period in February 2019. Each household recorded daily food waste data, ensuring consistency across all

study locations. To maintain accuracy and completeness, field researchers actively monitored the data collection process.

To provide a comprehensive and reliable dataset, this study utilized a large and diverse sample of 2,700 households, surpassing previous research efforts in this field. Compared with similar studies, the extended 28-day data collection period enhances the robustness of the findings, offering a more detailed temporal assessment [5, 24, 37].

The selection of study locations was strategically guided by considerations of regional distribution, socio-demographic diversity, and variation in waste management practices. Four provinces—Lamphun, Lop Buri, Loei, and Songkhla—were selected to represent Thailand's four geographic regions: North, Central, Northeast, and South China. These provinces were chosen on the basis of their diverse geographic, demographic, and socioeconomic characteristics, allowing for a comprehensive analysis of food waste generation patterns in both urban and rural settings.

Additionally, these four provinces have been recognized for their exemplary waste management performance, having received the Cleanest Province Award from the Department of Local Administration, Ministry of Interior. Their strong leadership in environmental governance and waste management programs made them ideal for this study, as local authorities were cooperative and had the capacity to support research efforts through data collection and community engagement initiatives. This facilitated data reliability and enabled a more effective assessment of food waste generation behaviors across different administrative structures.

To ensure a balanced and representative dataset, nine study sites were selected across these four provinces, accounting for a variety of economic activities and population densities. The site selection process adhered to the Department of Provincial Administration's guidelines, ensuring an equitable distribution of urban and rural communities. Specifically, the study sites were chosen from two types of local administrative organizations: subdistrict municipalities (SM), which represent urban communities with populations exceeding 7,000 and densities of at least 1,500 people per square kilometer, and subdistrict administration organizations (SAO), which represent rural communities with populations of at least 2,000. Within each of the nine study sites, we encompassed 10 villages, sampling 30 households per village, which resulted in a total of 300 households per site. This comprehensive approach culminated in the participation of 2,700 households, as detailed in Table 1.

The analysis of food waste generation rates should encompass data collected on both weekdays and holidays [5, 37]. This research was designed to collect data directly from household sources of food waste over a four-week period. The procedure quantified waste in both the liquid and solid portions. The analysis included both avoidable and unavoidable food waste [38]. Unavoidable food waste is defined as food that is not and has never been edible under normal circumstances [39]. Examples include bones, carcasses, eggshells, peels, fruit skins, apple cores, and coffee grounds. In contrast, avoidable food waste refers to edible food that could have been consumed but is disposed of for various reasons [40]. However, this study did not categorize waste into these two specific types in detail. Instead, the research focused on quantifying total food waste generation rates across different regions and community types. The data collection process specifically separates liquid portions from total food waste, ensuring that the moisture content is less than 60% for accurate greenhouse gas (GHG) generation evaluations, as recommended by Eggleston et al. [41].

Figure 1 illustrates the systematic food waste measurement process employed in this study, which uses a household-based direct measurement approach to ensure data accuracy. Before data collection, volunteers underwent both onsite and online training to standardize the data recording procedures, use digital weighing scales, and properly handle food waste separation. Each participating household was instructed to record their daily food waste over a continuous 28-day period using their own waste containers, following standardized measurement and documentation guidelines provided by the research team.

The measurement process involved weighing the empty bins first, followed by recording the total weight of the collected food waste, including both solid and liquid components. The liquid portion was then separated, and the solid waste was weighed again to distinguish between waste compositions. Volunteers meticulously documented food waste quantities before and after liquid separation via a standardized data collection template, and additional household socioeconomic data, such as household size, income levels, and consumption behaviors, were also recorded. To ensure data reliability, field researchers conducted random verification checks, and weekly data aggregation was performed to account for fluctuations in waste generation. This structured methodology enables a precise assessment of food waste generation rates across urban and rural households in Thailand, producing a robust dataset covering 2,700 households from four provinces to analyze regional variations in food waste patterns.

Table 1 Characteristics of each sample site, code, and number of collected samples

Community characteristics	Province	Locala administration	Sample site code	Number of households	Raw data collected (1 week)	Average weekly data (4 weeks)	Average weekly data (4 weeks) (Excluding 3% outliers)
Urban community	Lamphun	U-Mong	N1	300	2,100	1,200	1,160
	Lamphun	Mae Rang	N2	300	2,100	1,200	1,160
	Lop Buri	Po Talat Kaew	C1	300	2,100	1,200	1,160
	Loei	Chiangklom	NE1	300	2,100	1,200	1,160
	Songkhla	Pawong	S1	300	2,100	1,200	1,160
Rural community	Lamphun	Ban Puang	N3	300	2,100	1,200	1,160
	Lop Buri	Kong Thanu	C2	300	2,100	1,200	1,160
	Loei	Pha Samyod	NE2	300	2,100	1,200	1,160
	Songkhla	Rattaphoom	S2	300	2,100	1,200	1,160
Total				2,700	18,900	10,800	10,440

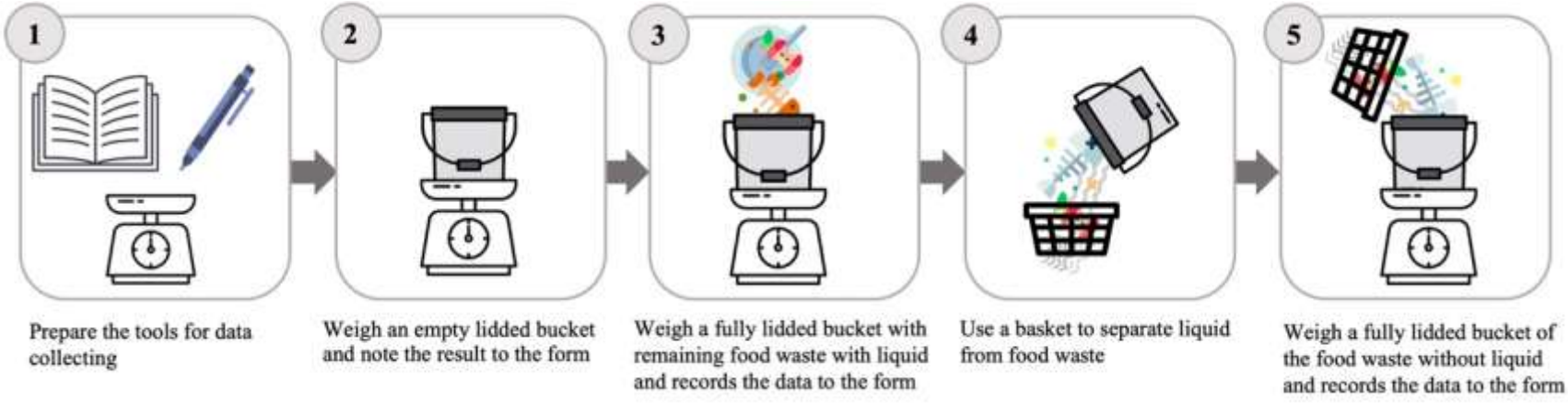

Figure 1 Data collection methods.

2) Quality assessment and quality control for analysis

The quality of the dataset and the repeatability of the measurement results were rigorously ensured through meticulous data collection and analysis procedures. Primary data on food waste generation rates were systematically gathered and analyzed weekly, accounting for both liquid and solid waste components. To maintain data integrity, robust quality control measures were implemented, including the identification and removal of anomalous data that could skew the results. This process, facilitated by the IBM SPSS Statistics Data Editor Version 2, involved the exclusion of outliers that could significantly affect the statistical analyses.

The outliers were identified and removed via the interquartile range (IQR) method, where data points exceeding 1.5 times the IQR were classified as extreme values. This method helps eliminate irregular data caused by recording errors or abnormal household waste disposal behaviors. The total raw dataset consisted of 75,600 daily records (2,700 households × 28 days). Since the study analyzed weekly averages for each household, the data were aggregated into 2,700 household records per week, totaling 10,800 weekly records before outlier removal. After excluding approximately 3% of the outliers, the final dataset retained approximately 10,400 valid records for analysis.

The researchers organized the data in descending order, revealing a skewed distribution that indicated low variability. A total of 10,440 data points were subsequently subjected to analysis, as summarized in Table 1. Notably, only a small fraction—three percent (360 data points)—was identified as unsuitable for inclusion in the analysis, as highlighted by the red circle in Figure 2. Importantly, potential outliers may arise from errors in data recording and collection by volunteers. Therefore, meticulous identification and removal of such inaccuracies are essential to enhance the accuracy and reliability of the analysis.

Results and discussion

1) The rate of food waste generation

Following the removal of outlier data, an analysis of food waste generation rates was conducted for each study site via SPSS software. As shown in Table 2, site C2 (Kong Thanu, a rural community in the Central Region) recorded the highest food waste generation rate, including liquid, at 0.565±0.011 kg per capita per day. Conversely, site N3 (Ban Puang, a rural community in the northern region) and site NE1 (Chiangklom, an urban community in Northeast Thailand) presented the lowest waste generation rates, at 0.194±0.002 kg per capita per day and 0.194±0.003 kg per capita per day, respectively.

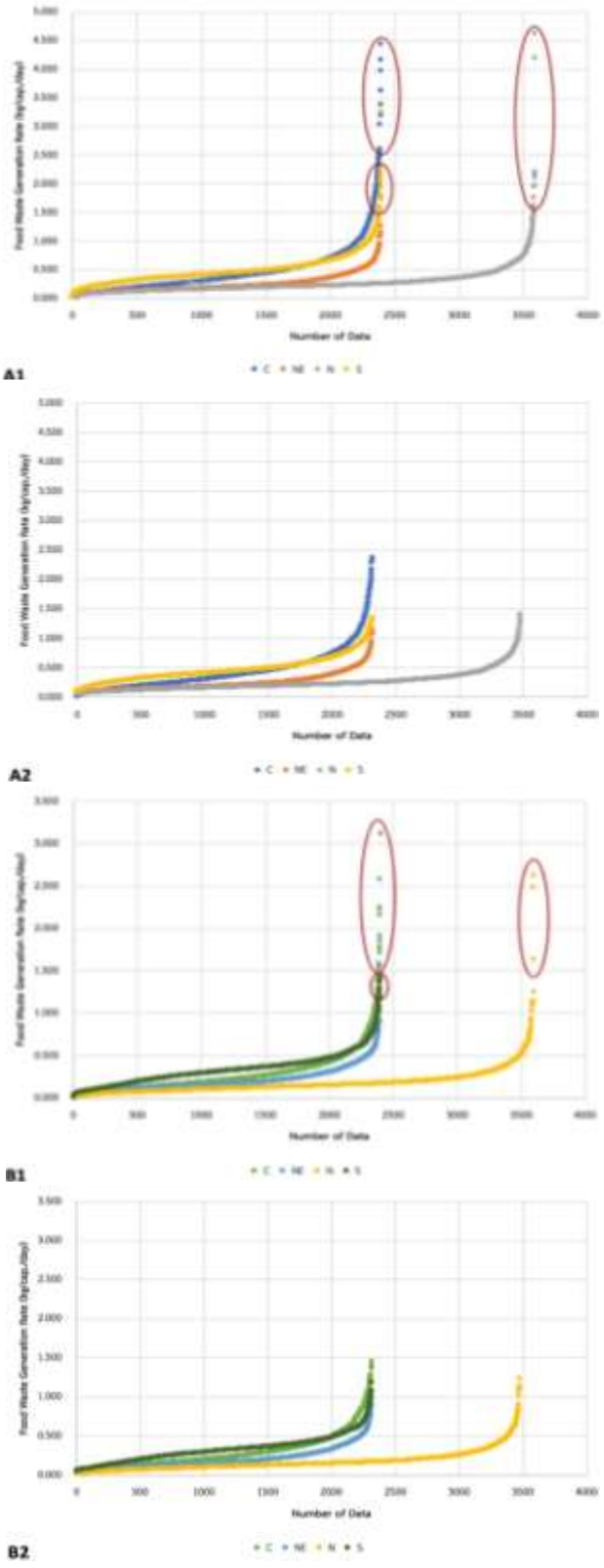

Figure 2 Comparison of the generation rates of food waste (A) including liquid and (B) excluding liquid of all the samples. A1 refers to the data including liquid before outlier removal; A2 refers to the data including liquid after outlier removal; B1 refers to the data excluding liquid before outlier removal; B2 refers to the data excluding liquid after outlier removal.

To better understand regional food waste dynamics, waste generation rates were analyzed in relation to community type and geographic location. Notably, site C2, which recorded the highest food waste rate, is a rural community where home-prepared meals and large household sizes contribute to higher food waste volumes. In contrast, site NE1, classified as urban, presented the lowest waste generation rate because of a higher prevalence of processed and convenience foods, which tend to produce less organic waste. Moreover, site N3, although rural, had significantly lower waste generation, possibly due to localized food conservation practices and variations in household consumption behavior. These findings highlight regional and community-specific factors influencing food waste generation rather than a simple rural–urban divide.

The results indicate that the proportion of liquid waste was 25.75% in urban communities and 33.16% in rural communities. Among the individual sites, C2 (rural, central) had the highest liquid waste proportion at 52.2%, whereas NE2 (rural, Northeast) had the lowest at 11.2%. Notably, the highest and lowest proportions were consistently found in rural areas, highlighting significant regional variations in food preparation and consumption behaviors. These findings suggest that rural communities tend to generate a greater share of liquid food waste, possibly because of more frequent home cooking and traditional food processing methods.

These findings suggest that rural communities discard a greater proportion of liquid waste than urban areas do, likely due to differences in food preparation methods and dietary habits. and the availability of fresh, home-cooked meals. However, the results of the Pearson correlation analysis indicate a negative relationship between household income and food waste generation at most rural sites. Significant negative correlations were observed for N2 ($r = -0.116$, $p < 0.05$), C1 ($r = -0.174$, $p < 0.05$), and C2 ($r = -0.231$, $p < 0.05$), suggesting that in these areas, higher-income households tend to generate less food waste, potentially due to better food management practices or reduced surplus food stockpiling.

Table 2 Analysis of the sample group's data

Sample site code	Food waste including liquid (kg per capita per day)			Food waste excluding liquid (kg per capita per day)			Correlations with household income	Paired samples test
	Average	Standard deviation	Variance	Average	Standard deviation	Variance	Sig. (2-tailed)	Sig. (2-tailed)
N1 [U]	0.320± 0.005	0.185	0.034	0.227± 0.004	0.139	0.019	-0.027	0.002 [b]
N2 [U]	0.211± 0.005	0.171	0.029	0.125± 0.004	0.140	0.020	-0.116[a]	
N3 [R]	0.194± 0.002	0.056	0.003	0.132± 0.001	0.044	0.002	-0.035	
C1 [U]	0.296± 0.007	0.229	0.053	0.262± 0.006	0.209	0.044	-0.174 [a]	0.000 [b]
C2 [R]	0.565± 0.011	0.371	0.138	0.270± 0.006	0.202	0.041	-0.231 [a]	
NE1 [U]	0.194± 0.003	0.103	0.011	0.148± 0.002	0.079	0.006	0.019	0.000 [b]
NE2 [R]	0.278± 0.005	0.169	0.028	0.247± 0.004	0.147	0.022	0.087	
S1 [U]	0.463± 0.004	0.138	0.019	0.353± 0.003	0.107	0.011	-0.039	0.552
S2 [R]	0.4656± 0.008	0.257	0.066	0.292± 0.006	0.198	0.039	-0.101	

Remark: [a] Food waste generation rate, including liquid, is significantly related to household income at the 95% confidence level.

[b] Food waste generation rates, including liquid, significantly differ between urban and rural communities at the 95% confidence level.

[U] Urban community

[R] Rural community

In contrast, at urban sites such as NE1 ($r = 0.019$, $p > 0.05$) and NE2 ($r = 0.087$, $p > 0.05$), the correlations were weak or nonsignificant. The weak correlations in urban areas imply that income alone may not be a strong determinant of food waste generation, as other factors, such as food consumption patterns, dining habits, and waste management practices, are likely to play a more influential role.

This challenges previous studies suggesting that urban households always generate less food waste than rural households do, highlighting the complex dynamics of waste generation influenced by regional and socioeconomic factors [42–43]. Additionally, variations in liquid waste proportions across regions may be linked to differences in consumption behaviors, food processing methods, and waste disposal practices.

Statistical analysis confirmed a significant difference ($p < 0.05$) in liquid waste proportions between urban and rural households, as well as across regions. Further analysis of site pairings at the 95% confidence level revealed significant variations among C1-C2, NE1-NE2, and N1-N3, whereas no significant difference was detected between S1 and S2, likely due to sample size variations.

Moreover, Songkhla (S), the most densely populated region (1.433 million residents, 194.21 persons per km² in 2018), exhibited distinct waste generation patterns, reinforcing the impact of demographic and geographic factors on food waste behaviors. Understanding these complex relationships is crucial for designing targeted food waste reduction policies that align with regional consumption behaviors and socioeconomic conditions.

A comprehensive nationwide data collection was conducted, encompassing information gathered from 2,700 households over a meticulous 28-day period. The distributions of household food waste rates, both including and excluding liquid waste, as illustrated in Figures 3(A) and 3(B), demonstrate consistent patterns. Comparative analysis of waste generation rates via standard mean and normal distribution methods yielded congruent results, reinforcing the reliability of the primary dataset underpinning this analysis. Consequently, the food waste rates derived from the normal average analysis can be considered representative of Thailand's overall food waste landscape.

The synthesized food waste generation rates for the entire country can be summarized as follows: the average rate of food waste generation, including liquid, was 0.332±0.003 kg per capita per day, with a standard deviation (SD) of 0.242 and a variance of 0.059. Conversely, the average rate of food waste generation, excluding liquid, was 0.228±0.002 kg per capita per day, with an SD of 0.242 and a variance of 0.168, as detailed in Table 3. The low variance observed suggests relative coherence in the data with minimal dispersion. However, given the extensive dataset collected, the food waste generated, including liquid, is regarded as indicative of the overall food waste generation rate in Thai households. This finding aligns with prior research by Liu, et al. [44], who estimated that food waste generation in Bangkok was 0.38-0.61 kg per day in 2018.

An examination of the relationship between household income and food waste generation rates reveals notable insights. Among the sample group, 50% of the households reported a monthly income of less than 10,000 baht, whereas 38% fell within the income bracket of 10,001-20,000 baht, 9% earned between 20,001-30,000 baht, and 3% had incomes exceeding 30,001 baht per month.

The analysis reveals a statistically significant positive correlation between household income and food waste generation rates in rural areas ($p < 0.05$, $r = 0.057$), suggesting that higher-income rural households tend to generate more food waste. However, this correlation is not statistically significant in urban areas ($p > 0.05$, $r = 0.005$) or at the national level ($p > 0.05$, $r = 0.237$), indicating that other factors—such as food purchasing habits, waste disposal practices, and local infrastructure—may play a more influential role in these settings.

This finding contrasts with those of several prior studies [45–47], which suggest that higher disposable income in urban areas leads to greater food waste generation due to higher consumption of convenience foods, larger meal portions, and increased dining out. However, in this study, no significant correlation was observed in urban settings, implying that income alone may not be a primary driver of food waste. Instead, urban households might be influenced by factors such as waste management policies, food storage efficiency, and environmental awareness.

Conversely, the positive correlation observed in rural areas suggests that higher-income rural households may have larger household sizes, more frequent home-cooked meals, and greater agricultural food waste, leading to increased food waste generation. This highlights the need for targeted waste reduction strategies in rural areas, such as food preservation education, improved waste separation practices, and local composting programs.

At the national level, the weak overall correlation reinforces the idea that income alone is not a dominant factor in food waste generation across Thailand. Policymakers should adopt region-specific interventions that consider behavioral, cultural, and infrastructure-related influences on food waste to address waste management challenges effectively.

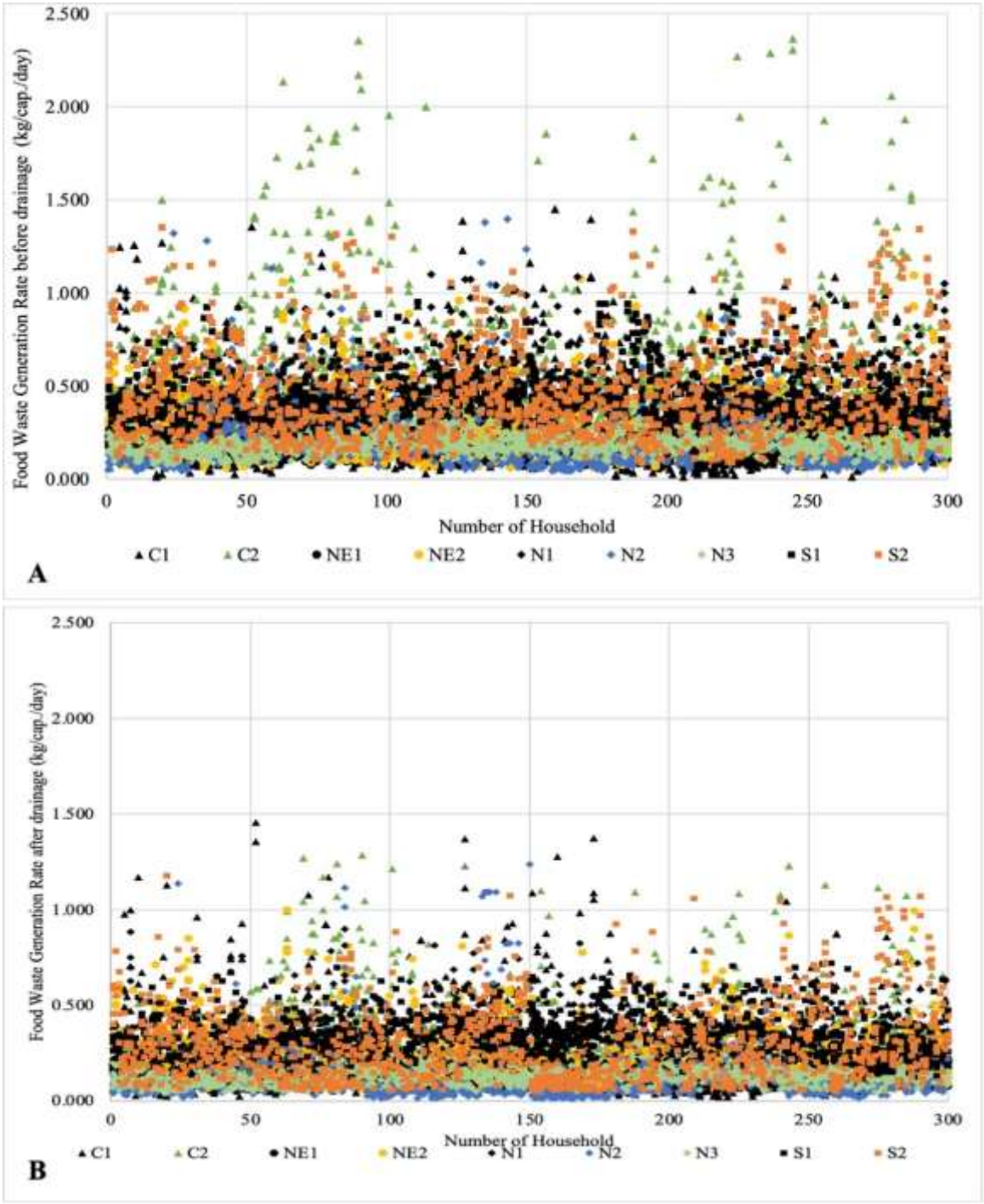

Figure 3 Distribution rates of food waste, including liquid (A) and excluding liquid (B), in several areas and the whole country.

2) Comparative analysis of food waste generation rates across countries

A comparative analysis of food waste generation rates across various countries, as summarized in Table 4, provides an essential context for interpreting the results of this study. Significant disparities exist in global food waste generation rates, which are influenced by factors such as consumption habits, waste prevention policies, and socioeconomic conditions. For example, the Netherlands reported the highest food waste rate of 0.904 kg capita per day, whereas Iran reported the lowest rate of 0.076 kg capita per day. Interestingly, food waste rates do not always align with a country's economic status or GDP, as demonstrated by the United Kingdom's relatively low rate of 0.199 kg capita per day, despite being a developed country, in contrast to the higher rates observed in other high-income nations such as Canada, Sweden, Denmark, and the Netherlands.

In Thailand, previous research conducted by the PCD [10] reported a food waste generation rate of 0.716 kg capita per day on the basis of data collected from landfill sites. In contrast, this study, which collected primary data directly from households, revealed an average food waste generation rate of 0.332±0.003 kg

capita per day. The disparities in these findings can be attributed to variations in data collection methodologies and shifts in consumption behaviors over time, as discussed by Daniel Hoornweg and Perinaz Bhada-Tata [48] and Kaza Silpa, et al. [2].

Notably, the methodologies employed in data collection varied across studies, resulting in differences in sample sizes and data collection periods. Some studies relied on smaller sample sizes, such as a minimum of 13 households [29], whereas others, including the present study, utilized larger sample sizes of up to 2,700 households. Additionally, the data collection periods ranged from as short as 7 days [5] to as long as 4 months [32], with some capturing seasonal variations in food waste generation [49]. The methods employed, including questionnaire surveys, food waste diaries, and landfill data analysis, also influence findings, emphasizing the need for standardized food waste measurement approaches to enable more accurate cross-country comparisons.

By situating Thailand's food waste generation rate within a broader global context, this comparative analysis reinforces the importance of methodological rigor and highlights how regional differences, socioeconomic factors, and waste management policies shape food waste trends. These insights can inform future policy interventions and waste management strategies aimed at reducing food waste at the household level.

3) Projection of future household food waste trends in Thailand

To anticipate future trends in household food waste generation in Thailand, the current food waste rate, including liquid (0.332 ± 0.003 kg per capita per day), was utilized to model the expected waste output across the entire Thai population from 2009-2029. Four scenarios were devised to account for varying population growth rates:

A. An average annual population increase of 0.19% [54]

B. The average annual population increase was 0.44%, which was based on growth rates observed from 2009-2019 [55]

C. The average annual population increase was 0.61%, which is in line with trends observed in the Asia–Pacific region [56]

D. The average annual population increase of 1.1% reflects global population growth trends [56]

In 2019, household food waste in Thailand totaled 8.2 million tons. Projections for 2029, under scenarios A, B, C, and D, suggest that waste volumes may increase to 8.3, 8.5, 8.7, and 9.1 million tons, respectively (Figure 4). These projections underscore the critical need for robust food waste management strategies that integrate both waste prevention and sustainable disposal solutions. The most effective strategy is waste reduction at the source, which is achieved through awareness campaigns, improved food labeling policies, and responsible consumption initiatives.

At the household and municipal levels, improving waste separation programs can enhance food waste collection and processing, reduce the contamination of recyclables and increase the efficiency of organic waste treatment. The promotion of composting and anaerobic digestion can support nutrient recycling, contribute to soil enhancement, and promote sustainable agriculture.

Table 3 Rates of food waste in Thailand (kg per capita per day)

	Urban community		Rural community		The whole country	
	Food waste including liquid	**Food waste excluding liquid**	**Food waste including liquid**	**Food waste excluding liquid**	**Food waste including liquid**	**Food waste excluding liquid**
Average	0.315±0.002	0.220±0.002	0.336±0.003	0.224±0.002	0.332±0.003	0.228±0.002
SD	0.235	0.162	0.243	0.161	0.243	0.168
Variance	0.055	0.026	0.059	0.026	0.059	0.028
Correlations with household Income	0.005		0.057 [a]		0.237	
Food waste generation rates between urban and rural communities using independent samples t test			0.000 [b]			

Remark: [a] The food waste generation rate, including liquid, is significantly related to household income at the 95% confidence level.
[b] The food waste generation rates, including liquid rates, significantly differ between urban and rural communities at the 95% confidence level.

Table 4 Comparison of food waste generation rates by country and methodology

Food waste generation rate (kg per capita per day)	Countries	Methods	Number of household sampling unit	Duration	Status	GDP	Reference
0.076	Iran	Primary data & questionnaire	1,197 households	1 week	Developing countries	$1,266.69 billion	[5]
0.155	Bangladesh	Primary data & questionnaire	75 households	6 months	Developing countries	$91.63 billion	[45]
0.199	Austria	Kitchen diaries (primary data)	30 households	1 week	Developed countries	$391.9 billion	[29]
0.199	United Kingdom	Primary data	13 households	2 weeks	Developed countries	$2.441 trillion	[29]
0.200	Germany	N/A	442 households	N/A	Developed countries	$3.478 trillion	[37]
0.234	Canada	Primary data	54 households	2 weeks	Developed countries	$1.557 trillion	[24]
0.242	China	Primary data	113 households	10 days	Developing countries	$5.11 trillion	[50]
0.250	Czech Republic	Primary data	10 households	20 weeks	Developed countries	$49,774 million	[31]
0.285	Vietnam	Primary data	100 households	2 seasons	Developing countries	$115.9 billion	[49]
0.332	**Thailand**	**Primary data**	**2,700 households**	**4 weeks**	**Developing countries**	**$205.6 billion**	**This study**
0.442	Finland	food waste diary	380 households	2 weeks	Developed countries	$256.7 billion	[51]
0.548	Sweden	Primary data & questionnaire	61 households	4 months	Developed countries	$543.9 billion	[32]
0.557	Denmark	Primary data	1474 households	1 week	Developed countries	$306.9 billion	[37]
0.600	Canada	Primary data	20, 28 and 41 households	3 months	Developed countries	$1.549 trillion	[52]
0.716	Thailand	Primary data at land fill	121 municipality	N/A	Developing countries	$172.9 billion	[10]
0.904	Netherland	Primary data	110 households	N/A	Developed countries	$866.7 billion	[53]

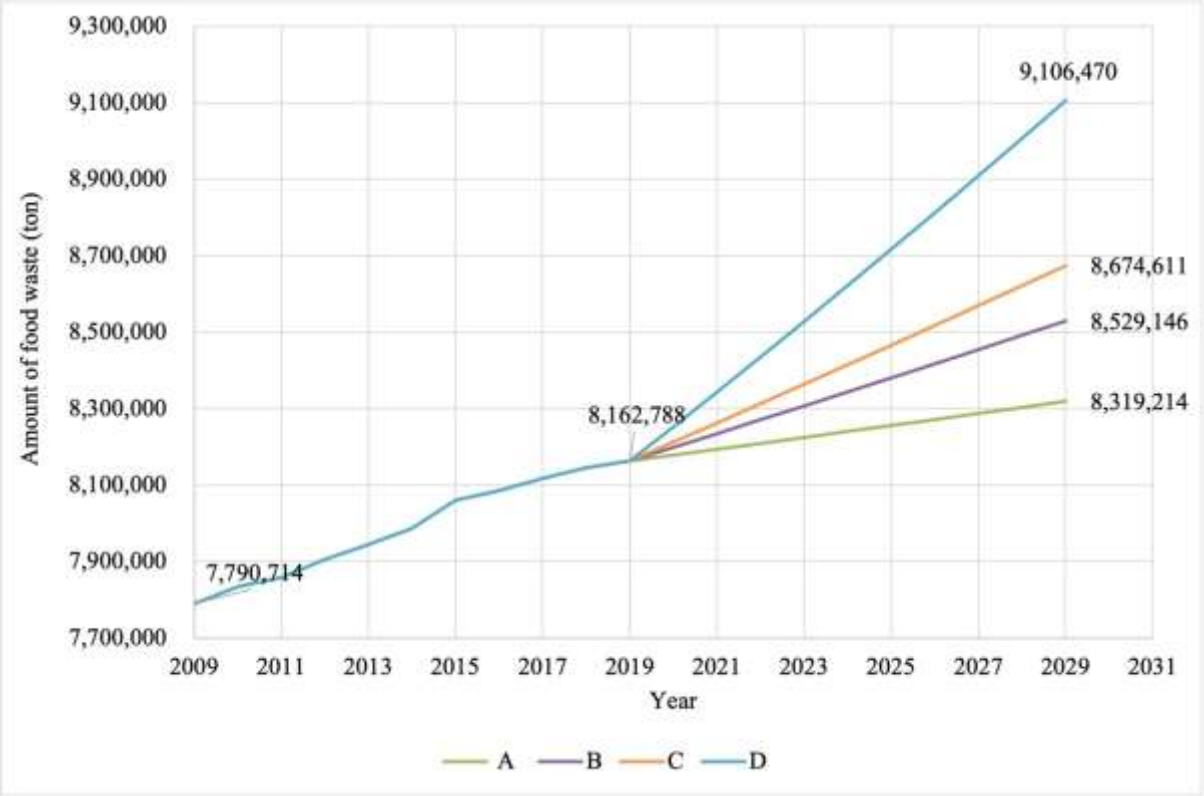

Figure 4 Amount of food waste (tons) from various scenarios. When A is an average annual population increase of 0.19%, B is an average annual population increase of 0.44%, based on growth rates observed from 2009-2019, C is an average annual population increase of 0.61%, in line with trends observed in the Asia-Pacific region and D is an average annual population increase of 1.1%, reflecting global population growth trends.

Additionally, waste-to-energy (WtE) technologies provide a viable alternative for food waste utilization, particularly in urban settings where landfill capacity is limited. Expanding WtE solutions [57], such as anaerobic digestion and biogas production, can enhance Thailand's transition to a circular economy, reducing reliance on landfills and mitigating greenhouse gas emissions [58].

From a policy perspective, Thailand can align its national food waste management framework with international goals, particularly Sustainable Development Goal (SDG) 12.3, which seeks to halve global food waste by 2030. Integrating food waste reduction into Thailand's Bio-Circular-Green (BCG) Economy Model would further promote waste valorization through biofertilizers, biogas, and animal feed production, ensuring that food waste is efficiently repurposed [59].

To further strengthen national efforts, Thailand's National Roadmap on FLW should be expanded to include mandatory food waste separation programs, incentives for municipal composting infrastructure, and extended producer responsibility (EPR) programs targeting food retailers and manufacturers. These measures reinforce waste diversion efforts and promote sustainable consumption and production practices.

Internationally, Thailand can adopt best practices from countries that have successfully reduced food waste. South Korea's Pay-As-You-Throw (PAYT) system has significantly reduced household food waste generation by charging fees on the basis of waste volume, encouraging waste minimization and segregation [60]. Similarly, France's strict food donation laws have minimized supermarket food waste, ensuring that surplus food is redistributed rather than discarded [61]. The implementation of similar policies in Thailand—such as mandatory food waste reporting for businesses and incentivized food donation programs—could help drive behavioral change and corporate responsibility in food waste management.

Ultimately, the implementation of a structured food waste management system that combines prevention, waste separation, recycling, and WtE solutions will be key to mitigating Thailand's growing food waste challenge. The development of incentives for businesses, municipalities, and households to engage in sustainable waste practices will also accelerate the transition toward a low-waste society, ensuring that Thailand moves toward a more resource-efficient and environmentally sustainable future.

Conclusions

This study addresses the lack of detailed food waste generation data in Thailand by conducting a large-scale primary data collection effort at the household level. Over a 28-day period, food waste samples—including

both liquid and nonliquid components—were systematically collected from 2,700 households across urban and rural areas. The findings revealed an average food waste generation rate of 0.332±0.003 kg per capita day, including liquid, and 0.228±0.002 kg per capita day, excluding liquid. This dataset represents the most extensive food waste measurement effort conducted in Thailand, providing a robust foundation for national-level waste management assessments.

A key insight from this study is the significant disparity in food waste generation rates between urban and rural communities. Contrary to common assumptions, rural households produced higher preliquid separation food waste rates than their urban counterparts did. This trend is likely influenced by differences in food consumption habits, with rural households engaging more in home cooking—which generates higher organic waste volumes—while urban households increasingly rely on prepackaged and processed foods, which results in lower direct food waste but contributes to packaging waste.

Moreover, a positive correlation was identified between household income and food waste generation, particularly in urban areas, suggesting that higher-income households tend to generate more food waste. This highlights the importance of targeted waste reduction strategies, such as consumer awareness campaigns, improved portion control, and food donation programs, to mitigate avoidable food waste—particularly among affluent households.

These findings provide critical insights for policy-makers aiming to develop effective food waste management frameworks. Aligning national strategies with SDG 12, which focuses on sustainable consumption and production, is essential. Future policies should prioritize waste prevention at the source, improved food waste segregation and collection, and the expansion of circular economy solutions, such as composting, biogas production, and WtE technologies. Strengthening municipal waste management policies and incentivizing household- and business-level waste reduction efforts will be instrumental in moving Thailand toward a more sustainable and resource-efficient future.

Limitations

This study offers key insights into food waste generation in Thai households but has limitations. While it includes both avoidable and unavoidable food waste, a detailed breakdown was not conducted. Future research should analyze waste composition to identify preventable food waste.

Data collection relied on self-reported measurements, which may introduce reporting biases despite standardized training and verification. Additionally, the study covered a single 28-day period in February 2019, limiting insights into seasonal variations. Expanding data collection across multiple seasons would improve accuracy.

Geographically, the study focused on four provinces (Lamphun, Lop Buri, Loei, and Songkhla), which, while diverse, may not fully represent highly urbanized areas such as Bangkok. The inclusion of larger metropolitan regions and varied waste management infrastructures would enhance generalizability.

Finally, the study did not assess the behavioral or policy aspects of food waste reduction. Future research should integrate behavioral studies and policy evaluations to develop more effective waste mitigation strategies.

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