

# Quantification and classification of food waste from hotels and restaurants in Bali as a potential database towards sustainable food waste management

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**Abstract.** Bali is globally recognized as a prominent tourist destination, which results in substantial food waste generated by hotels and restaurants. However, there has yet to be a scientific study or report on the quantity and classification of this waste. This research aimed to gather quantitative data and categorize the types of food waste produced by hotels and restaurants in Bali. The research design included purposively selecting the population and sample, utilizing questionnaires for data collection, analyzing the data, and presenting the results descriptively. The findings revealed that hotels generate significantly more food waste than restaurants across various categories. On average, hotels produce approximately 2,137.20 kg of food waste per month. The largest amounts of waste originate from cooking oil (386.40 kg/hotel/month), vegetables (295.20 kg/hotel/month), and meat (271.20 kg/hotel/month). In comparison, restaurants generate an average of 1,634.88 kg of food waste per establishment each month, with the most substantial quantities coming from fruits (741.46 kg/restaurant/month), shellfish (417.00 kg/restaurant/month), and fish (177.60 kg/restaurant/month). These findings underscore the importance of effective food waste management in hotels and restaurants in Bali, as they present significant opportunities for developing various value-added products.

## 1 Introduction

In recent years, the issue of food waste has attracted considerable attention from various stakeholders, including food producers, processors, retailers, and consumers. This challenge is becoming more pressing as food loss and waste continue to increase alongside rising food

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prices and widespread food insecurity. Food waste is recognized not only as a sustainability challenge linked to food security but also as an economic concern that directly impacts the profitability of the entire food supply chain. Over the past two decades, organic waste, particularly food waste, has emerged as a critical issue that demands urgent attention. This specific type of organic waste has profoundly affected the global environment, society, and economy [1]. Food waste represents a complex, multidimensional challenge with economic, social, and environmental implications for sustainable development. Notably, the food service industry is a major contributor to this problem, responsible for approximately 11 million tons of waste. Furthermore, food waste is estimated to account for 3.3 gigatons of carbon emissions, making it the third largest global emitter of greenhouse gases, after the United States and China. According to the United Nations Environment Programme (UNEP) report titled *Food Waste Index 2021*, Indonesia ranks first in Southeast Asia for food waste production, generating an astounding 20.93 million tons annually [2].

Food waste management has emerged as a critical issue for stakeholders across various industries worldwide, yet there remains a significant gap in research focusing on food waste management specifically within the hospitality sector, particularly in developing countries [3]. The tourism industry comprises diverse businesses, including destinations, attractions, accommodations, restaurants, catering services, festivals, and events. Depending on the type of establishment and its hygiene standards, an estimated 20–60% of food purchased by hotels ends up in the waste bin [4]. This waste considerably impacts climate change, contributing approximately 186 million tons of CO<sub>2</sub> equivalent emissions in Europe. In Bali, the tourism sector has exacerbated waste management challenges, leading to overwhelmed landfills. The island has ten landfills, five nearing capacity, and two that are already overfilled. This situation poses a risk of pollution and can detract from the quality of tourist destinations. Implementing effective strategies to reduce food waste is crucial for mitigating environmental impacts [4]. Such efforts demand comprehensive solutions and approaches to decrease the food waste generated and curb unnecessary consumption.

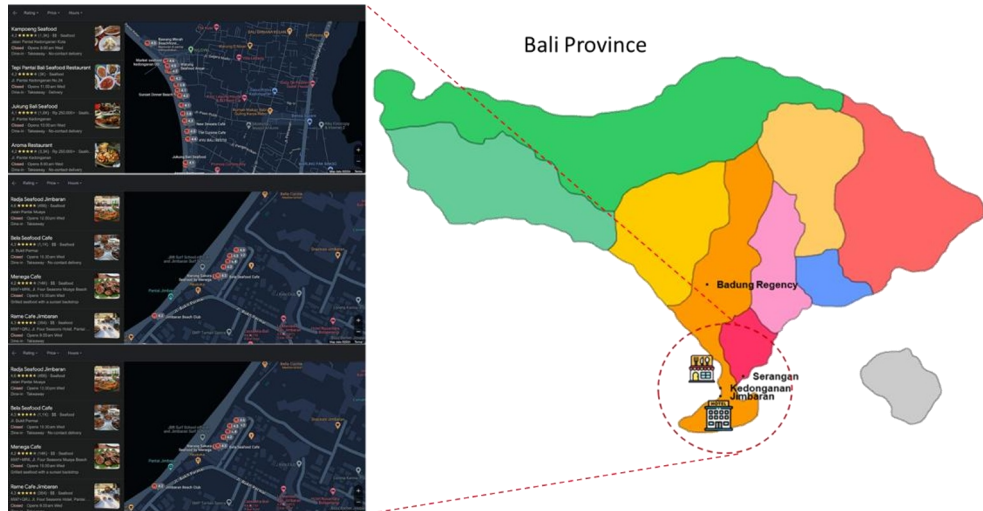
Numerous initiatives have been undertaken to tackle the issue of food waste in various contexts. However, there remains a lack of documented information regarding the quantity, classification, rates, characteristics, and potential of food waste, specifically from hotels and restaurants in Bali. Therefore, gathering this data to support further research, especially concerning management and utilization strategies, is essential. This study seeks to collect quantitative data and classify the types of food waste generated by hotels and restaurants in Bali. Conducting this research is urgent, as it aligns with local government policies, and the findings can be communicated to relevant stakeholders.

## **2 Material and method**

### **2.1 Population and sample**

The study was conducted between April and November 2024, focusing on hotels and restaurants in Bali. The sample selection utilized purposive sampling, determined by specific criteria, such as consistently high occupancy rates and buffet-style food presentations. This survey study employed both qualitative and quantitative approaches. Research was carried out in both starred and non-starred hotels located in the Kuta-Nusa Dua (Badung) and Sanur (Denpasar) areas, which are premier tourist destinations in Bali with a substantial number of hotels. Information regarding food waste management practices implemented by the hotels was obtained through interviews. Specifically, the research on food waste from restaurants was conducted across three locations: Serangan Village (Denpasar), Jimbaran Village, and Kedonganan Village (Badung). The sample comprised 50 entities, evenly split between 25

hotels and 25 restaurants. The distribution of the research areas is illustrated in Figure 1. The percentage of respondents from the Serangan, Jimbaran, and Kedonganan areas was 36%, 38%, and 26%, respectively. Notably, seafood restaurants are predominant in this tourist region.



**Fig. 1.** Area and distribution of research samples

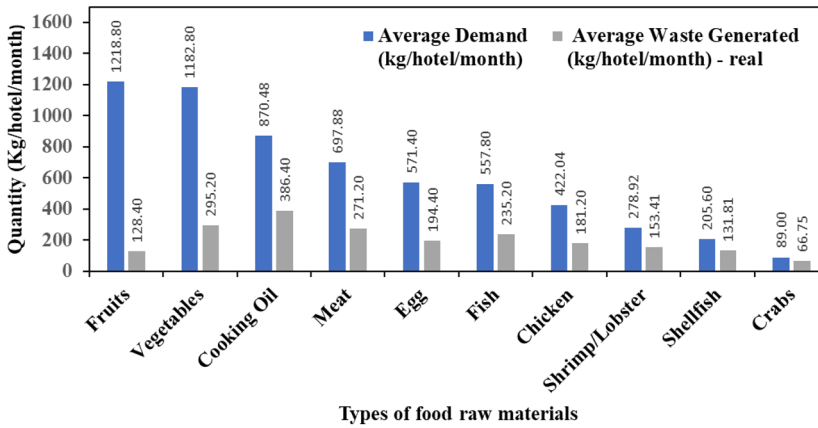
## 2.2 Data collection and analysis

The data collected in this study consists of both qualitative and quantitative information. Qualitative data were gathered through interviews with stakeholders, focusing on the implementation of waste sorting, reduction, and recycling practices. The data analysis employed descriptive statistics, specifically calculating the average values for the quantity of raw material demand and the amount of food waste generated. The findings are presented through average values, tables, and graphs to enhance clarity and interpretation of the research results. The percentage of food waste is calculated by determining the ratio of the average weight of food material demand for each hotel or restaurant to the average amount of food waste produced, expressed in units of kg per hotel per month.

## 3 Results and discussion

### 3.1 Quantification and classification of food waste

The comparison of the demand for food raw materials and the waste generated over one month in the hotel is illustrated in Figure 2. Fruits and vegetables exhibit the highest demand, at 1,218.80 kg per hotel per month and 1,182.80 kg per hotel per month, respectively. Despite fruits having the most significant demand, their associated waste is notably lower compared to that of vegetables. Conversely, with a demand of 870.48 kg per hotel per month, cooking oil produces the highest amount of waste cooking oil (WCO), totaling 386.40 kg per hotel per month. In contrast, the demand for shellfish and crabs is relatively low, at 205.60 kg per hotel per month and 89.00 kg per hotel per month, respectively. However, these items generate a significant percentage of waste, accounting for 64% and 75% of the raw materials, respectively, as shown in Table 1.

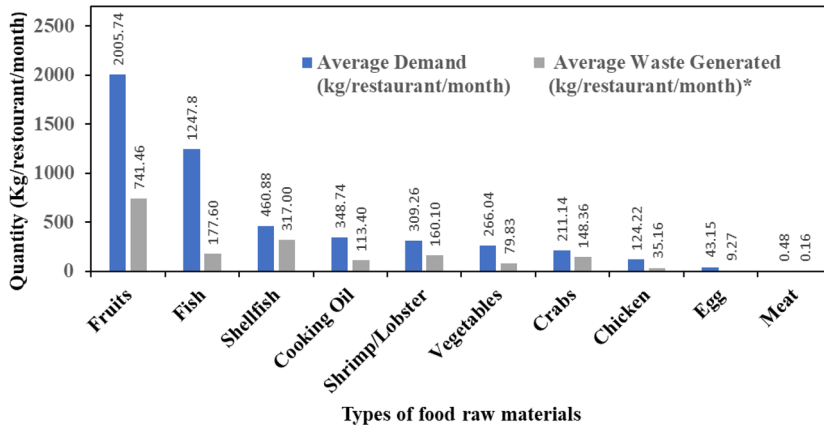


**Fig. 2.** Quantity of types of raw material demand and waste produced by hotels in Bali

**Table 1.** Percentage of the quantity of food waste generated from raw materials used by hotels in Bali

Raw materials	Types of waste	Waste generated
Fruits	Orange peel, coconut shell	10.53%
Vegetables	Cabbage	24.96%
Cooking Oil	Waste cooking oil (WCO)	44.39%
Meat	Blood, fat	38.86%
Egg	Shell	34.02%
Fish	Fins, innards, and bone	42.17%
Chicken	Bone	42.93%
Shrimp/Lobster	Shell	55.00%
Shellfish	Shell	64.11%
Crabs	Shell	75.00%

Currently, fruits and fish exhibit the highest demand in restaurants, with an average consumption of 2,005.74 kg per restaurant per month and 1,247.8 kg per restaurant per month, respectively. In contrast, the lowest demand is observed for eggs and meat, which are consumed at rates of 43.15 kg per restaurant per month and 0.48 kg per restaurant per month, respectively, as illustrated in Figure 3. Fruits and shellfish also generate the most waste, producing 741.46 kg per restaurant per month and 314.00 kg per restaurant per month, respectively. On the other hand, egg and meat products result in the least waste, averaging around 1.16 kg per restaurant per month. This trend aligns with restaurants in Serangan, Jimbaran, and Kedonganan Villages, predominantly seafood establishments, where the use of eggs and meat remains relatively low. Notably, crabs, shellfish, and shrimp/lobster account for a significant percentage of waste, generating 70.26%, 68.78%, and 51.77% of the raw materials, respectively, as detailed in Table 2.



**Fig. 3.** Quantity of types of raw material demand and waste produced by restaurants in Bali

**Table 2.** Percentage of quantity of food waste generated from raw materials used by restaurants in Bali

Raw materials	Types of waste	Waste generated
Fruits	Orange Peels	36.97%
Fish	Fins, Innards and Bone	14.23%
Shellfish	Shell	68.78%
Cooking Oil	WCO	32.52%
Shrimp/Lobster	Shell	51.77%
Vegetables	Water Spinach	30.01%
Crabs	Shell	70.26%
Chicken	Bone	35.16%
Egg	Shell	21.49%
Meat	Blood, Fat	34.17%

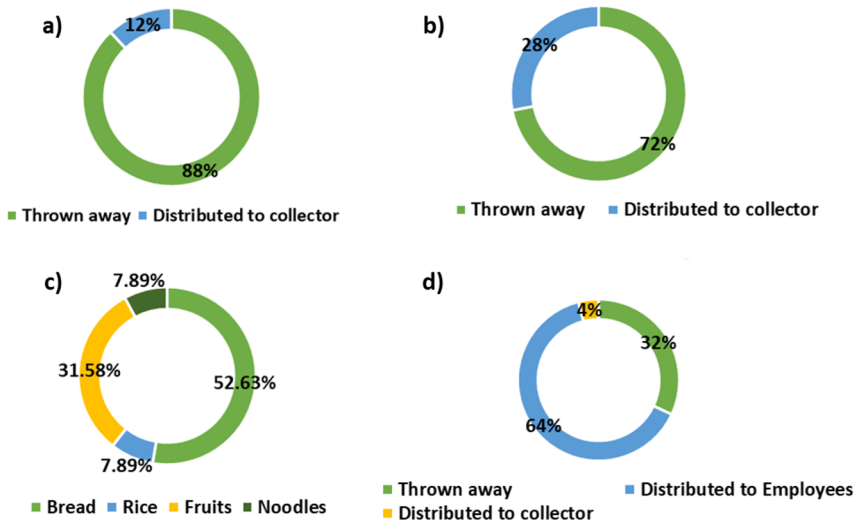
The types of fruit waste generated in hotels and restaurants are notably high, particularly with items like orange peels and coconut shells. Demand for various fruits also varies between hotels and restaurants. Hotels primarily require large quantities of watermelon, pineapple, and melon, whereas restaurants have a higher demand for coconut, watermelon, and orange. Regarding fish, hotels predominantly seek tuna and snapper, while restaurants favor snapper and grouper. The processing of these fish results in waste, which includes fins, innards, and bones, accounting for 14.23% to 42.17% of the total. The percentage of food waste generated by hotels and restaurants can differ significantly based on factors such as the type of food, raw materials used, processing methods, and presentation styles. Various studies have reported potential waste generation percentages for different commodities. For instance, fruits and vegetables can produce waste of approximately 23.00% to 23.02% [5], fish waste is estimated at around 35.00% [6], chicken waste at 30.27% [7], meat waste ranges from 3.71% to 19.00% [8], while shrimp or lobster can generate 55.00% waste, and crab can reach up to 75.00%. Additionally, shellfish such as clams and scallops create waste around 64.11% [9], eggs produce 12.00% waste, and coconut oil has a waste percentage of 30.00% [10].

Food waste generated from hotels and restaurants can vary in quantity and composition, affecting the recycling method. This food waste can be generated from various stages, from procurement to consumption. The amount of food waste generated by hotels and restaurants is influenced by multiple factors, including hotel capacity, room rates, garden availability,

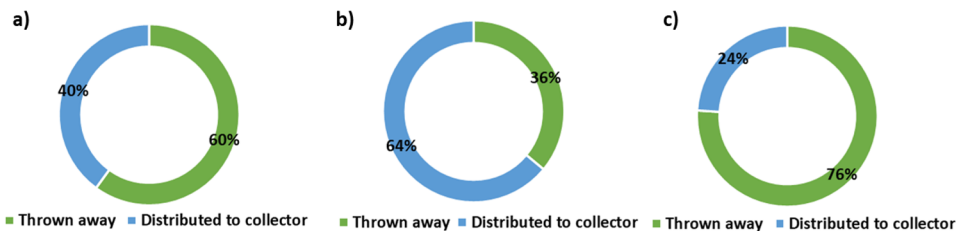
and restaurant service levels [11]. Several researchers have measured the quantity of food waste in grams per meal at the storage, preparation, and serving stages. In addition, classification was also carried out on the level of food waste accumulation at the food preparation stage, serving waste, and leftover food on plates. Generally, the types of waste generated by food can be classified into two types: avoidable and unavoidable [3].

### 3.2 Food waste handling

Waste management typically follows a conventional model that involves collecting, transporting, and disposing waste. This model heavily relies on the capacity of the final disposal site, and most of the waste produced only undergoes minimal processing before disposal [11]. In the context of food waste management in hotels, about 12% is passed on to collectors, while nearly 88% ends up in the trash, as illustrated in Figure 4a. Regarding cooking oil waste, only 28% is sent to collectors for reuse (Figure 4b). The predominant types of food waste generated include bread, which comprises approximately 52.63%, and fruit, accounting for around 31.58%. This food waste is managed by distributing 68% to workers and collectors, as shown in Figure 4d. For other types of waste, vegetables are distributed to collectors at a rate of 40%, used cooking oil at 64%, and various different types of waste produced by restaurants at 24%, as depicted in Figure 5.



**Fig. 4.** Methods for handling food waste in hotels: a) general handling, b) cooking oil waste, c) leftover type, d) leftover handling



**Fig. 5.** Methods for handling food waste in restaurants: a) vegetable waste, b) cooking oil waste, c) other types of waste

### **3.3 Characteristics and application potential of food waste.**

Food waste possesses a wide range of characteristics. Caldeira et al. [12] highlighted various nutrients found in fruit, vegetables, milk, meat, and fish waste that can be repurposed in food products, such as gelling agents in snacks, fat substitutes in meat products, food additives, and seafood flavorings for soups [12]. Additionally, food waste is regarded as a renewable energy source that could significantly reduce our reliance on fossil fuels. While food waste can certainly be utilized for composting, it's important to maintain an optimal carbon-to-nitrogen (C/N) ratio. Ideally, this ratio should be around 25-30 (dry weight) before composting, and should decrease to about 12-15 (dry weight) once the composting process is complete. In the case of food and yard waste from the Nusa Dua tourist attraction, the reported C/N ratios are 41.19 and 43.8, respectively, indicating that this ratio must be adjusted to enhance the composting process [11].

The characteristics and potential utilization of food waste produced by hotels and restaurants in Bali, namely orange peel is reported to contain cellulose (4.4 wt%), hemicellulose (10.9 wt%), lignin (1.3 wt%), pectin, polyphenols, flavonoids, carotenoids, and vitamins (28.7 wt%) which have the potential to be used as materials for amino acids, nanoparticle precursor agents, growth stimulants and biofortification [13]. Coconut shells contain cellulose (36.13%), hemicellulose (20.36%), and lignin (32.33%) which have the potential to be used as liquid smoke and tannin [14]. Cabbage waste contains various bioactive compounds, glucosinolates, flavonoids, antioxidants which can be used as a source of bioactive compounds and animal feed. Water spinach contains water content (72.83%), ash (10.83%), crude fat (11.00%), crude fiber (17.67%), and carbohydrates (54.20%), crude protein content (6.30%) has the potential to be used as animal feed, water spinach powder. Waste cooking oil and fat contains fatty acids (oleic acid, palmitic acid, linoleic acid, stearic acid) which have the potential to be used as raw materials for biofuel, biolubricants, plasticizers and surfactants. Fish blood contains proteins, lipids, and small molecules that have the potential to be applied as food and feed, and peptide bioactivity. Shells contain calcium carbonate, protein, chitin, lipids, and pigments that have the potential to be used as animal feed, cosmetics and pharmaceuticals, building materials, and absorbents [15]. Fins and innards contain protein, fat, and carbohydrates and have the potential to be used as animal feed, fish meal, and fertilizer. Meanwhile, fish and chicken bone waste contains calcium, phosphorus, protein, fat and other minerals that have the potential to be used for bone meal, fertilizer, animal feed, gelatin, soil improvement, calcium carbonate, calcium fluoride and calcium phosphate [6].

## **4 Conclusions**

Hotels generate more food waste than restaurants across categories. Hotels generate an average of 2,137.20 kg of food waste per hotel per month, which accounts for about 35.07% of their average food demand of 6,094.72 kg per hotel per month. The primary sources of this waste include fruits, vegetables, cooking oil, meat, eggs, fish, chicken, shrimp, lobster, shellfish, and crab. The most significant amount of waste comes from cooking oil (386.40 kg per hotel per month), vegetables (295.20 kg per hotel per month), meat (271.20 kg per hotel per month), and fish (235.20 kg per hotel per month). In contrast, restaurants generate an average of 1,634.88 kg of food waste per restaurant per month, which accounts for about 32.58% of their average food demand of 5,094.72 kg per restaurant per month. The sources of waste in restaurants also include fruits, fish, shellfish, cooking oil, shrimp, lobster, vegetables, crab, chicken, eggs, and meat. The most significant amount of waste generated by restaurants comes from fruits (741.46 kg per restaurant per month), shellfish (417.00 kg per restaurant per month), fish (177.60 kg per restaurant per month), and cooking oil (113.40

kg per restaurant per month). Given these findings, it is clear that food waste generated by hotels and restaurants in Bali requires effective management, as it provides significant opportunities for developing various value-added products.

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