JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(7), 198–208
https://doi.org/10.12911/22998993/164749
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.03.30
Accepted: 2023.05.15
Published: 2023.05.24

Analysis of Food Industry Waste Management Based-On the Food Recovery Hierarchy and 3R Concept – A Case Study in Padang City, West Sumatra, Indonesia

Yommi Dewilda[1*], Mhd. Fauzi[2], Rizki Aziz[1], Fahrum Dian Utami[1]

[1] Department of Environmental Engineering, Universitas Andalas, Padang City 25175, Indonesia
[2] Doctoral Student of Environmental Engineering, Institut Teknologi Bandung, Bandung City 40132, Indonesia
* Corresponding author's e-mail: yommidewilda@eng.unand.ac.id

ABSTRACT

This research goal was to analyze food industry waste in Padang City based on Food Recovery Hierarchy and 3R concept. Waste sampling refers to SNI 19-3964-1994 with 35 sampling points spread across 6 types of food industries. According to the sampling result which includes waste generation, composition, and characteristics, the management of the food industry in Padang City was studied based on the principles of Food Recovery Hierarchy and 3R Concept. The result of the study showed that waste generated is 27.44 tons/day or equivalent to 250.31 m^3/day with the organic waste as the largest contributor having percentage of 85.06%. On the basis of the chemical and biological characteristics, such as water content, C/N ratio, and biodegradability fraction, the waste shows that the most compatible treatment for the waste is biological treatment with composting. First step in the principles of Food Recovery Hierarchy is applying the concept of waste reduction to the waste resulted from each industry in as many as 2.19% or 4.83 kg/day. In the second step, 44.295 or 99.92 kg/day of the waste were given to livestock. The third step involved composting 39.27% or 86.72% of the waste. The fourth step was to do landfilling with 1.77% or 3.90 kg/day of the waste. The fifth step was selling 12.48% or 25.40 kg/day of the waste that has a recycling potential to collectors based on the 3R concept. If these concepts are applied, the waste taken to the dumpsite will decrease from 16.24 tons/day to 0.49 tons/day.

Keywords: 3R concept, analysis, food industry, food recovery hierarchy, Padang City, waste management.

INTRODUCTION

Improper collection of 33% of world's annual municipal waste is equivalent to 0.663 billion tons of waste and it is estimated that by 2050 it will grow to 3.40 billion tons (Kaza et al., 2018). Waste not only causes problems in the disposal process but also constitutes a major contributor to greenhouse gases with total contribution around 5% of global emissions (Hoa and Matsuoka, 2017; Jaunich et al., 2019). Limited data on waste generation and characteristics in developing countries makes it difficult for governments to develop efficient and sustainable waste management programs (Ogwueleka, 2009; Olukanni et al., 2014). If an area is unable to manage waste effectively, it will be difficult to manage more complex public services issues such as health, education, and transportation services (De Clercq et al., 2017; Ishtiaq et al., 2018).

The increasing population, phenomena of rapid urbanization, as well as economic growth and rising living standards in developing countries have caused the amount of waste to accelerate (Minghua et al., 2009). Rapid population growth will have an impact on various activities that can generate waste with different variations and quantities. If there is no ability and willingness from the citizens of the country to manage waste problems, then it can be a very serious problem. The problems which could be caused by this include health problems (Upadhyay et al., 2012; Kumar et al., 2017), environmental pollution, and environmental aesthetics issues (Ferronato et al., 2018). In addition to environmental impacts, waste management must also consider its impact to economic development and the role of society (Ding et al., 2021; Huang et al., 2020).

Waste problems can arise from various sources, one of which is from the food industry sector. The food industry produces waste from various activities carried out. The waste generated is in the form of organic and inorganic waste. The waste generated is usually immediately disposed of to the nearest containers. In accordance with the second clause of Indonesia's Waste Management Law No. 18 of 2008, the refuse generated from industrial zones is categorized as domestic waste. As outlined in clause 12 of the aforementioned legislation, individuals responsible for the administration of household and household-like waste must undertake the measures to minimize and dispose of waste in an ecologically responsible manner.

The city of Padang is the capital of West Sumatra Province, characterized by a high population density which is followed by industrial growth. On the basis of the data from the Industry and Labor Agency for the City of Padang in 2017, the City of Padang has 1,121 food industry units. Types of food industry in the city of Padang include chips, bakery, soybeans (tofu and tempeh), coffee, dried fish, dried noodles, and others. The large number and various types of food industries in the city of Padang cause waste problems from the manufacturing process to the product packaging. It causes a complex problem which is difficult to handle (Abdel-Shafy and Mansour 2018; Burnley, 2008). It still raises an issue, even though this waste contains materials that can be recycled (paper, plastic, glass, metal) as well as organic materials (food scraps, vegetables, fruit peels) that can be composted (Fauzi et al., 2022; Gupta et al., 2015; Kolekar et al., 2016).

Ruslinda and Veronika (2013) conducted a study on industrial waste generation in Padang City with a waste generation unit from the snack food industry of 0.009 kg/person/day. In addition, the research related to the study of food industry waste generation in Padang City was conducted by Dewilda and Warnares (2020) with the results of an average generation study of 0.005 kg/production/day for large industries, 0.083 kg/production/day for medium industries and 0.262 kg/production/day for small industry. The difference of this research and the previous research of food waste is that this research studies treatment of food waste from industry sector. In addition, the waste collected is not based on the industrial scale, but on the type of waste-producing industry.

According to Regional Regulation of the City of Padang No. 21 of 2012 article 8 where the manager of residential areas, commercial areas, industrial areas, special areas, public facilities, social facilities, and other facilities are required to sort and provide waste sorting facilities. However, what often happens in the field is that industrial waste is mixed and not sorted at the source. According to Dewilda and Warnares (2020) the waste that has been produced by the food industry is collected and disposed of at the local TPS (Temporary Disposal Site) without any prior processing. Thus, it is necessary to study the management of food industry waste in Padang City using the Food Recovery Hierarchy and the 3R Concept, so that each food industry can manage the waste it produces and reduce the waste that goes to the TPA/dumpsite. This method of waste management has a tiered hierarchy in the form of an inverted pyramid. Each level of the hierarchy focuses on a different strategy for managing food waste. The campaigns regarding food recovery hierarchy that are carried out include waste reduction in sources, food donation, feeding animals, industrial use, composting, incineration, and landfilling. The management strategy in the food recovery hierarchy and the 3R concept is an idea that can be applied to waste management in the food industry.

MATERIALS AND METHODS

Secondary data collection

According to the data from the Padang City Industry and Labor Agency in 2017, there were 1,121 food industries registered in Padang City. The number and types of food industries in Padang City can be seen in Table 1.

Determination of the number and location of sampling points

The number of sample points obtained using SNI 19-3964-1994 concerning Methods for Taking and Measuring Sample Generation and Composition of Municipal Solid Waste are:

$$S = C_d \sqrt{T_s} = 1 \sqrt{1121} = 35 \quad (1)$$

Table 1. Types of food industries in Padang City

No	Industry type	Number of industry
1	Sauce & soy sauce	10
2	Noodles	10
3	Processed soybean	61
4	Coffee	15
5	Packaged drinks	87
6	Bakery	382
7	Crackers and chips	394
8	Fishery	45
9	Meat	15
10	Others	102
Total		1.121

Note: Padang City industry and labor agency, 2017.

The total number of waste sampling points is 35 with a survey reliability of 98.25% which falls within the 90–100% confidence level range. This means that 35 samples have represented a total of 1,121 food industries in the city of Padang. On the basis of Table 1, the 6 types of industries with the highest number were selected, which represented 85% of the total food industry in Padang City. The determination of samples number in each industry can be seen in Table 2. The chosen sampling points are the food industry with longer operating hours than other food industries and the food industry which agreed to serve as a sampling point.

Primary data collection

Sampling was carried out for 8 consecutive days at the same location. Waste samples were collected for 24 hours. Sampling stages implemented in this research are based on SNI 19-3964-199. Weight and volume measurements were carried out for each waste sample. Measurement of waste composition was also carried out by measuring waste based on its components. The composition was divided into 4 types, namely organic components, plastics, paper, and others (Dewilda et al., 2019; Dewilda et al., 2022). The characteristics of the waste measured were physical characteristics in the form of specific gravity, chemical characteristics in the form of proximate analysis and C/N ratio, and biological characteristics in the form of biodegradability fraction. Analysis of the potential for waste recycling was carried out based on the existing conditions of the sample. The potential for recycling of waste was determined by sorting the waste that can be recycled according to its composition. After that, the waste was weighed; then, the weight and percentage of the waste that has the potential to be recycled was recorded according to the waste component data purchased by the waste business actors.

Study and implementation of food industry waste management in Padang City

Preliminary study and implementation food industry waste management in Padang City feasibility is limited to management based on food recovery hierarchy, namely: reduction at source, food donation for people in need, giving waste to animals as animal feed, industrial use, composting, and landfill (USEPA, 2016). Besides that, it also uses the 3R concept.

RESULTS AND DISCUSSION

Waste generation

On the basis of Figure 1, bakery industry is the food industry with highest average waste generation in terms of volume at 560.04 liters/day, while in terms of weight it is the soybean industry at 71.22 kg/day. The fishery has the least waste generation, where the waste generated is 1.09 kg/day based on weight and 2.31 liters/day based on volume. The waste from this industry only comes from fish scales.

Table 2. Number of samples in chosen industries

No	Industry	Number	%	Samples number
1	Coffee	15	1.65	2
2	Soybean	65	7.14	8
3	Chips	394	43.25	10
4	Noodles	10	1.09	2
5	Bakery	382	41.93	10
6	Fishery	45	4.94	3
Total		911	100.00	35

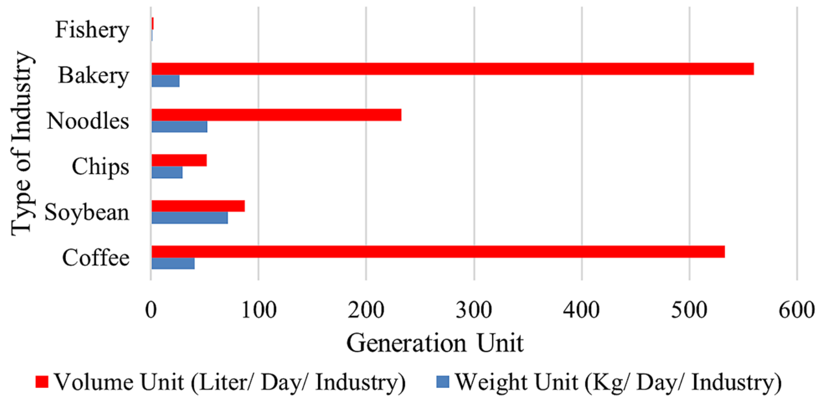

Figure 1. Waste generation of food industry in Padang City

Table 3. Total of waste generation from padang city food industry

Industry	Number of industry	Waste Generation	
		Weight unit (Kg/day)	Volume unit (Liter/day)
Coffee industry	15	609.23	7,997.19
Soybean industry	65	4,628.95	5,652.91
Chips industry	394	11,475.44	20,291.43
Noodle industry	10	521.51	2,328.44
Bakery	382	10,155.30	21,3933.50
Fishery	45	48.88	104.10
Total	911	27,439.32	250,307.57

If multiplied by the respective number of food industries in the city of Padang, the yield for waste generation is 27.44 tons/day or 250.31 m^3/day. If each industry carries out waste management at each source, this number will be significantly reduced and minimize the amount of waste that goes to landfill. The total food industry waste generation in Padang City can be seen in Table 3.

Waste composition

The results of research on the waste composition from the food industry in Padang City showed that the highest composition was organic waste with an average percentage of 85.06%, while the composition with the lowest average percentage was other waste at 1.14%. The data for calculating the average waste composition of food industry waste in Padang City can be seen in Table 4.

The largest component of organic waste is food waste (bread, cake, and noodle flour) which comes from residue of the production process or production leftover with the percentage of 20.99%. Furthermore, other organic waste compositions are in the form of soybean dregs at 16.61%, fish scales at 16.67%, eggshells at 3.97%, coffee grounds at 10.27%, and sweet potato skins at 16.56%. The largest component for plastic waste is packaging plastic at 4.05%. Meanwhile, the percentage for plastic bags was 8.47%. The paper waste component only comes from cardboard waste at 1.27%. In turn, none of packaging paper and paper container was generated during the sampling process. Components for other waste only come from cans and other waste at 1.14%.

Waste characteristics

Chemical characteristics

According to (Table 5), it is known that waste from the food industry has a lower water content than volatile content. This is caused by the sample used that is not too wet. According to SNI 19-7030-2004 concerning Compost Quality Standards, the maximum water content of organic waste used for compost is 50%, thus, it shows that the waste from the food industry is suitable for composting. The organic C value was 15.66%, the total N value was 0.46% so that the C/N ratio of food industry waste in Padang City was 33.99%. The minimum C/N ration for composting is 25–50. The C/N ratio of food industry waste in the city of Padang can be seen in Table 6.

Table 4. Waste composition of Padang City food industry (%)

Waste component	Coffee industry	Soybean industry	Chips industry	Noodle industry	Bakery	Fishery	Average (%)
Organic							
Soybean dregs	-	99.64	-	-	-	-	16.61
Food	-	-	-	72.54	53.38	-	20.99
Fish scales	-	-	-	-	-	100	16.67
Eggshells	-	-	-	7.61	16.22	-	3.97
Coffee grounds	61.64	-	-	-	-	-	10.27
Sweet potato skin	-	-	99.35	-	-	-	16.56
Total organic	61.64	99.64	99.35	80.15	69.60	100	85.07
Plastic							
Plastic packaging	-	-	-	9.62	14.69	-	4.05
Plastic bag	38.36	0.36	0.65	7.25	4.19	-	8.47
Total plastic	38.36	0.36	0.65	16.87	18.88	-	12.52
Paper							
Cardboard	-	-	-	2.98	4.66	-	1.27
Total tissue/paper	-	-	-	2.98	4.66	-	1.27
Others							
Can	-	-	-	-	6.85	-	1.14
Total others	-	-	-	-	6.85	-	1.14
TOTAL							100

Table 5. Water content, volatile content, ash content, and fixed carbon

Chemical characteristic	Food industry						Average
	Coffee	Soybean	Chips	Dried noodle	Bread	Dried fish	
Water content (%)	29.33	38.49	18.46	27.11	20.84	34.57	28.14
Volatile content (%)	69.34	60.10	80.50	71.65	78.02	64.10	70.62
Ash content (%)	0.99	0.89	0.57	0.86	0.50	0.91	0.79
Fixed carbon content (%)	0.34	0.52	0.46	0.38	0.64	0.41	0.46

Table 6. C/N Ratio of waste industry in Padang City

Industry	C (%)	N (%)	C/N Ratio
Coffe	17.18	0.49	35.25
Soybean	14.21	0.50	28.25
Chips	16.12	0.42	38.15
Dried noodle	17.48	0.42	41.18
Bakery	15.59	0.53	29.28
Fishery	13.36	0.42	31.85
Rata-rata	15.66	0.46	33.99

Tabel 7. Biodegradability of Food Indsutry Waste in Padang City

Industry	Lignin content (%)	Biodegradability fraction (%)
Coffee	10.65	53.17
Soybean	4.20	71.23
Chips	8.27	59.83
Dried noodle	9.49	56.42
Bakery	8.80	58.37
Fishery	9.66	55.96
Average	8.51	59.16

Biological characteristics

Biological characteristic is tested through biodegradable analysis where the waste samples are conditioned according to the organic waste composition for each source. Biodegradability analysis was carried out after waste conditioning by measuring the lignin content contained in the waste samples. In the determination of lignin content, the waste sample being tested must be free from moisture content and volatile content beforehand, thus the sample needs to be heated at 550 °C. The results of measuring the biodegradability of waste from the food industry in Padang City can be seen in Table 7.

On the basis of the research results, it was found that the average lignin content was 8.51% and the average value of the biodegradable fraction was 59.16%. According to Tchobanoglous et al. (1993), if the value of the waste biodegradability fraction exceeds 50%, it can be said that the biodegradability value of waste is quite large. This means that organic waste from the food industry in Padang City has the ability to be decomposed into compost.

Study and implementation of food industry waste management in Padang City

Study of waste management using food recovery hierarchy

Preliminary feasibility study of food waste treament from the food industry in the city of Padang based on a food recovery hierarchy consisting of:

a) reduction at source – reduction at the source is limited to paper, plastic and can waste. The usage of these waste can be reduced by using substitute material or limiting its use at the source. The waste produced can be sold or given to scavengers;
b) food donation – waste that can be donated is the waste that is still suitable for consumption. An example of the waste that is fit for consumption is bread that is nearing an expiration date. The donated waste requires assistance from a third party to distribute it to those in need;
c) animal feeds – waste that can be used as animal feed is the waste that is feasible and suitable for livestock needs. This waste includes organic waste without containing coffee grounds, meat or waste with a high salt content;
d) industrial use – waste that can be utilized in industrial waste is the waste that can be converted to energy. For example, the waste that can be processed into energy in the form of biogas using the anaerobic digester method. One of the parameters that will affect the process that occurs in the anaerobic digester is the C/N ratio. The C/N ratio needs to be considered in the formation of biogas where the optimal standard for the anaerobic digester process ranges from 20–30 (according to Damanhuri and Padmi, 2016);
e) composting – composting activities can be carried out to reduce waste in the food industry in Padang City. The composting process can be done modestly or by using a tool. The characteristics of the waste required to be observed for the composting process include moisture content, C/N ratio and biodegradability of the waste.

The food recovery hierarchy method has similarities with the 3R (reduce, reuse, recycle) concept that is commonly applied in Indonesia. Waste reduction is part of reduce/R1, donating food and making it as animal feed is part of reuse/R2 and utilizing waste for industrial use and composting is part of recycle/R3. However, not every level of the applicable food recovery hierarchy is implemented by Padang City food Industry due to several factors such as the absence of food industry owners or employees' eagerness to do food donation or the absence of institutions or organizations to aid the food distribution. Industrial use, as the fourth tier of food recovery hierarchy, also has a limitation in the amount of waste generated for processing. Thus, only a few levels can be applied to the food industry in Padang City.

Study of waste management using 3R concept

Preliminary feasibility study of waste treatment from the food industry in Padang City based on the 3R concept consisting of:

Reduce/R1

The goal of the Reduce principle is to minimize waste production, especially at the end of production process. This stage can be done from the early part of the production by reducing raw materials for the production process. This shows that all production processes are basically capable of being endeavoured to produce as little waste as possible. This stage is carried out with a filtering system so that the waste generated automatically decreases, and vice versa. According to Nasir et al. (2015), a waste audit will help the food industry to identify the type of waste produced and make improvements. However, the issue in the food industry is the lack of ethos of food industry entrepreneurs towards waste audit implementation. In addition to the food industry entrepreneur ethos, support from individuals (such as employees), organizations (such as food industry management) and external support (such as government regulations) from the food industry is also needed.

According to Tekler et al. (2019), reducing waste at source requires support from individual, organizational and external factors. Individual factors are influenced by environmental awareness, attitudes, subjective norms, and behavioural control over waste management decisions. Waste management can save costs and help the environment. Organizational factors are related to waste management decisions and waste management policies. Support from external factors to reduce food industry waste is a training program and food industry policy decisions, which relate to waste management facilities to process and store the resulting food waste.

Waste reduction can be applied by replacing raw materials or materials that can generate large amounts of waste. This step is conducted to save costs and as a strategy to minimize expenses in purchasing materials. The reduction efforts that can be done include:

1. Choosing products with recyclable packaging;
2. Avoiding using and purchasing products that generate large amounts of waste;
3. Using products that can be refilled;
4. Reducing the use of disposable materials.

Reuse/R2

The Reuse/R2 principle is applied by directly utilize the produced waste. An example of the effort to apply reuse principle in Padang City food industry waste is using waste as animal feed. This is in accordance with the explanation from USEPA (2014), where food waste can be used as animal feed. However, the waste is not allowed to contain meat, contain coffee grounds, and a high salt content because it can harm animals. The use of organic waste or waste from the food industry that is suitable as animal feed includes:

1. Solid waste from chips processing can be used as chicken pellets also cattle and buffalo feed. This is in line with the research by Purnamasari et al., (2018) as solid waste processing chips contains crude protein and fiber;
2. Waste from noodles can be used as a mixture of duck and chicken feed. This is in accordance with the research of Widodo et al. (2010) where noodle waste has a fairly high nutritional content as animal feed. However, the maximum percentage of noodle waste that can be given as a mixture of animal feed can only be 20% of the total animal feed. This is because noodles are made from wheat which contain anti-nutritional substances that leads to reduction of the weight of chicken meat.
3. Waste from the bakery that will expire can be used as a mixture for duck feed and catfish feed. This is in accordance with the research of Akiki et al., (2014), where the use of bread waste as duck feed can increase duck body weight gain by 37%.
4. The chickens that are given tofu dregs as a feed combination gain weight by 15–24% in a year more than the chickens that are given commercial feed based on research by Kusumaningtyas et al., (2020).
5. Tofu dregs added to the same concentrate in sheep food do not interfere with the nutritional value of sheep food because it has the same crude fibre content value according to Yakin et al. (2019).
6. The high crude fibre content and the low nutritional content from cassava peels can be processed using fermentation technology for agile tilapia culture. The results obtained are the usage of cassava waste is considered good with doses above 25% for MEP+ probiotic inoculants in fermentation. (Akbar et al., 2014).
7. Noodle dregs can be used as animal feed, because they are rich in vitamins, minerals, protein, and starch. The utilization of recycled food waste for feed purposes is an effective method because it will make the country independent of feed and keep the environment clean (Karmee, 2016).

On the basis of the research that has been conducted on the food industry in Padang City, there are 20 food industries which include soybean industry, chips industry and bakery that have implemented the concept of turning waste into animal feed. Animals that utilize these food waste include cattle, buffalo, sheep, goats, and catfish. Usually, farmer picks up organic waste from the food industry in the afternoon or early morning. The food waste taken is in the form of soybean dregs, sweet potato skins and cassava cobs, as well as bread that approaches its expiration date.

Recycle/R3

The principle of recycle is recycling the remaining waste which cannot be utilize directly. Furthermore, the waste will be processed so it can be utilized, both as a raw material and as an energy source. Recycled waste from the food industry can be used for compost, anaerobic digesters or reprocessed into new products. Waste processing can be done by composting or anaerobic digestion. Both waste processing has their advantages and disadvantages as shown in Table 8.

According to Table 8, waste processing using the composting method is more effectively used for the food industry in Padang City. In addition to composting, the waste from the food industry in Padang City can be reprocessed into new products for sale. Processing waste into new products can reduce the waste generated from the food industry. Processing waste into a product with a selling value can minimize the waste generated by the food industry. Examples of waste processing into other products such as:

1. Coffee grounds waste can be used as a mixture of materials for interior products. This is in line with the research from Limantara et al. (2019) where products with a mixture of coffee grounds are lighter and have a smoother surface;
2. Waste from tofu production in the form of soybean dregs can be reprocessed into flour. This is in line with the research by Rahayu et al. (2016) and Putri et al. (2018) where the content of tofu dregs such as calories, carbohydrates, protein, and other elements is high;
3. Soybean dregs can be used to make rengginang which has a selling value which is in accordance with the research by Yustina (2011) who used soybean dregs as an ingredient for making rengginang;
4. Sweet potato skins can be used to make chips, flour, and liquid sugar. This is in accordance with the research of Aryani (2017) and Ulya (2018) who found out that sweet potato skins contain high nutritional content such as protein, fat, calcium, and carbohydrates;
5. Egg shell waste can be used as a substitute for baking soda composition in the manufacture of toothpaste, which is in line with the research from Syam (2016);
6. Fish skin and scales waste can be used to make chips which is in line with the research conducted by Kristianingrum et al., (2006) and Mulyani (2012). Fish skin and fish scales contains nutritional content.

Other than the examples mentioned above, animal feed processing can be included in the R3 (recycle) process in the form of processing for new products. The waste that will be used as animal feed should be processed before being given to livestock because it can cause harm, such as contamination from packaging materials, bacteria, uncooked sources, and inconsistent waste supplies. Thus, it is necessary to treat it first so that the food waste given to livestock does not have a bad impact. This processing is referred to as «Ecofeed (Ecological and Economical feed)» based on the research by Sugiura et al. (2009). The system for processing waste into Ecofeed starts with separating and collecting waste at the source, followed by sending the waste to the ecofeed manufacturing plant. After that, the dry ecofeed is brought to the farm to be used as feed mixture. The details for this process can be seen in Figure 2.

According to the findings of the study, composting design standards are restricted to water content, C/N ratio, and the biodegradability of waste. As per SNI 19-7030-2004, waste intended for composting must not exceed a moisture content of 50%. In comparison to the moisture content of the waste generated by the food industry in Padang City (28.14%), it satisfies the composting prerequisites. The ideal C/N ratio for composting ranges from 25–50 (Tchobanoglous et al., 1993). At

Table 8. Comparison between composting and anaerobic digestion

Parameter	Treatment alternative	
	Composting	Anaerobic Digestion
Technology	Stacked takakura method	Portable biodigester 1000 L
Energy utilization	Use energy	Produce energy
End-product	Humus, CO_2, H_2O	Sludge, CO_2, CH_4
Process duration	20–30 days	20–40 days
Volume reduction	More than 50%	More than 50%
Main goal	Volume reduction	Energy production
Other goal	Compost production	Volume reduction, waste stabilization
Aesthetic factor	No odor	Odor
Cost	Low	Expensive
Technical	Simple	Fabrication
Treatment scale	Treatment at source	Treatment at source

Note: Dewilda et al, 2019.

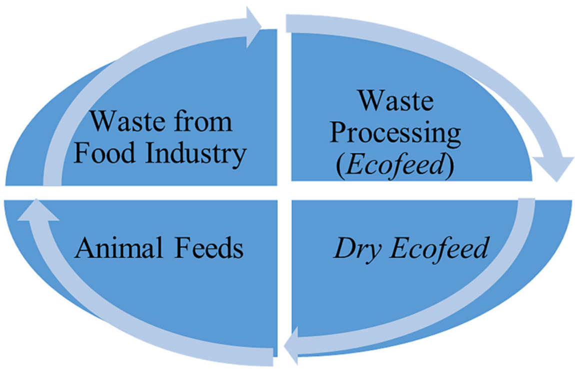

Figure 2. Ecofeed processing scheme

lower ratios, ammonia is released, which inhibits biological activity, while at higher ratios, nitrogen can be the limiting nutrient (Tchobagolus et al, 1993). The study results indicate that the C/N ratio of waste from the food industry in Padang City was 33.99, indicating that it meets the composting requirements.

As per the findings of Hayati (2013), a significant biodegradability quotient is considered to be anything over 50%. Accordingly, it can be established that the food industry waste in Padang City has a considerably high biodegradability quotient of 59.16%. This indicates that organic waste from the food industry in Padang City can be effectively transformed into compost. Upon comparing the waste characteristics and control parameters, it can be concluded that composting can be a viable alternative for treating waste from the food industry in Padang City. Additional information can be found in Table 9.

Table 9. Comparison between control parameters and characteristics from research result

Parameter	Design criteria	Research result	Note
Water content	Max. 50%	28.14%	Meet the criteria
C/N ratio	20–50	33.99	Meet the criteria
Biodegradibility	>50%	59.16%	Meet the criteria

Implementation of food industry waste management in Padang City

On the basis of the existing condition of food industry in Padang City, waste management can be done by using combination of food recovery hierarchy and 3R concept. Feasibility of food industry waste management using food recovery hierarchy implementation in Padang City showed in Figure 3. In turn, 12.48%, or 25.40 kg/day/industry, of the waste which is recyclable such as paper, plastic, which can be recycled and sold to scavenger, in line with third stage of 3R concept. Under the existing conditions, only 40.81% of the waste is well-managed, while the remaining 59.19%, or 16.24 ton/day are disposed to the TPA/dumpsite. If these two concepts implemented in each food industry, it will reduce the amount of waste entering the TPA/dumpsite to only 1.77% of the waste or equivalent to 0.49 ton/day.

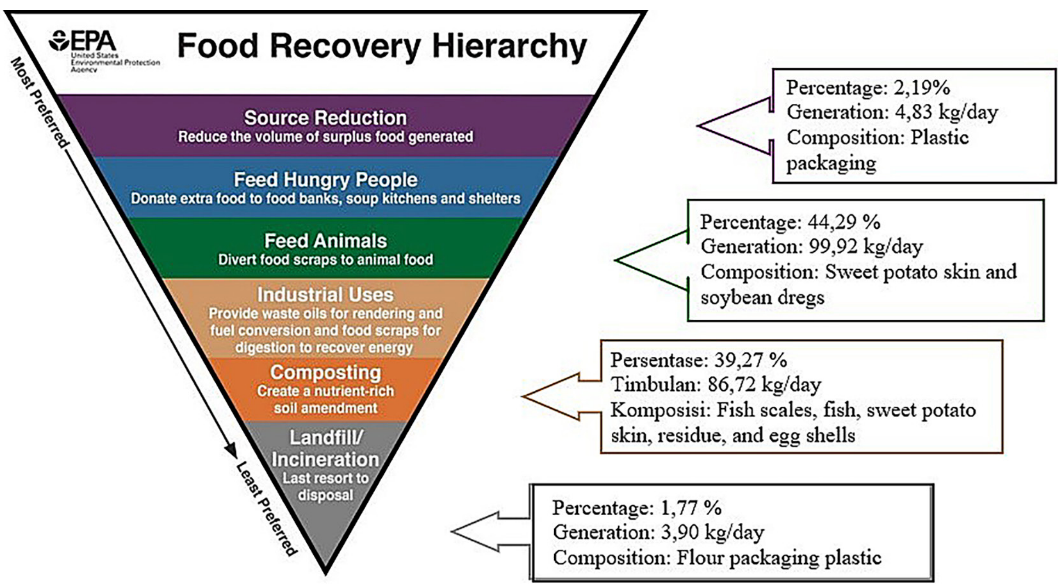

Figure 3. Percentage of food industry waste management according to food recovery hierarchy implementation in Padang City

CONCLUSIONS

Waste generation from food industry in Padang City reaches 27.44 ton/day or equivalent to 250.31 m^3/day. The waste is dominated by organic waste with percentage of 85.06% which has a suitable chemical and biological characteristic for biological treatment. Other than that, there also plastic, paper, and can waste which has potential to be recycled. Waste management using Food Recovery Hierarchy and 3R concept in every Padang City food industry will reduce the amount of waste that enters TPA/dumpsite from 16.24 ton/day to 0.49 ton/day.

REFERENCES

1. Abdel-Shafy H.I., Mansour, M.S.M. 2018. Solid Waste Issue: Sources, Composition Disposal, Recycling, and Valorization. Egyptian Journal of Petroleum, 27, 1275–1290.
2. Akbar, C.A., Sukanto., Rukayah, S. 2014. Kualitas pakan fementatif berbahan kulit ubi kayu dengan inokulan MEP+ untuk Kultur Ikan Nila Gesit (*Oreochromis nilaticus* L.). Scripta Biologica, 1(2), 141–145.
3. Akiki, A., Tafsin, M., dan Budi, U. 2014. Pemanfaatan Roti Afkir dalam Ransum terhadap Performans Itik Peking Umur 1-8 Minggu. Jurnal Peternakan Integratif, 2(3), 241–251.
4. Aryani, L., dan Triwardhani, D. 2017. IBM pada Kelompok Ibu-ibu Mengolah Kulit Singkong di Desa Cinere Kota Depok. Prosiding Seminar Nasional Penelitian dan PKM Sosial, Ekonomi dan Humaniora, 337–343.
5. Badan Standardisasi Nasional. 1994. Metode Pengambilan dan Pengukuran Contoh Timbulan dan Komposisi Sampah Perkotaan, Indonesia. Nomor Publikasi: SNI-19-3964-1994.
6. Badan Standardisasi Nasional. 1994. Spesifikasi Kompos dari Sampah Organis. Nomor Publikasi: SNI 19-7030-2004.
7. Burnley, S.J. 2007. A Review of Municipal Solid Waste Composition in the United Kingdom. Waste Management, 27(10), 1274–1285.
8. Damanhuri, E., dan Padmi, T. 2016. Pengelolaan Sampah Edisi I. Penerbit ITB: Bandung.
9. De Clercq, D., Wen, Z., Gottfried, O., Schmidt, F., Fei, F. 2017. A review of global strategies promoting the conversion of food waste to bioenergy via anaerobic digestion. Renewable and Sustainable Energy Reviews, 79, 204–221.
10. Dewilda, Y., dan Warnares, S.A. 2020. Study of generation, composition, characteristics, and recycling potential of industrial food waste in Padang City. Journal of Physics: Conference Series. IOP Publishing.
11. Dewilda, Y., Aziz, R., Fauzi, M. 2019. Kajian potensi daur ulang sampah makanan restoran di Kota Padang. Jurnal Serambi Engineering, 2(2), 482–487.
12. Dewilda, Y., Riansyah A., Fauzi, M. 2022. Kajian Pengelolaan Sampah Makanan Hotel di Kota Padang berdasarkan Food Recovery Hierarchy. Jurnal Serambi Engineering, 7(4), 3959–3970.
13. Dinas Perindustrian dan Tenaga Kerja Kota Padang. 2017. Data Industri IKM Pangan (DTKP) Kota Padang.
14. Ding, Y., Zhao, J., Liu, J.-W., Zhou, J., Cheng, L., Zhao, J., Shao, Z., Iris, Ç., Pan, B., Li, X., Hu, Z.-T. 2021. A review of China's municipal solid waste (MSW) and comparison with international regions: Management and technologies in treatment and resource utilization. J. Cleaner Prod., 293.
15. Fauzi, M., Darnas, Y., Aziz, R., Chyntia, N. 2022. Analisis Karakteristik dan Potensi Daur Ulang Sampah Non Domestik Kabupaten Solok selatan sebagai Upaya Meminimalisir Sampah ke TPA. Jurnal Serambi Engineering, 7(4).
16. Ferronato, N., Gorritty Portillo, M.A., Guisbert Lizarazu, E.G., Torretta, V., Bezzi, M., Ragazzi, M. 2018. The municipal solid waste management of La Paz (Bolivia): challenges and opportunities for a sustainable development. Waste Manag. Res, 36, 1–12.
17. Gupta, N., Yadav, K.K., Kumar, V. 2015. A review on current status of municipal solid waste management in India. Journal of Environmental Sciences, 37, 206–217.
18. Hoa, N.T., Matsuoka, Y. 2017. The analysis of greenhouse gas emissions/reductions in waste sector in Vietnam. Mitigation Adapt. Strateg. Global Change, 22(3), 427–446.
19. Huang, Q., Chen, G., Wang, Y., Xu, L., Chen, W.Q. 2020. Identifying the socioeconomic drivers of solid waste recycling in China for the period 2005–2017. Sci. Total Environ, 725, 138137.
20. Ishtiaq, P., Khan, S.A., Haq, M. 2018. A multi-criteria decision-making approach to rank supplier selection criteria for hospital waste management: a case from Pakistan. Waste Management.
21. Jaunich, M.K., Levis, J.W., DeCarolis, J.F., Barlaz, M.A., Ranjithan, S.R. 2019. Solid waste management policy implications on waste process choices and systemwide cost and greenhouse gas performance. Environ. Sci. Technol, 53(4), 1766–1775.
22. Karmee, S.K. 2016. Noodle Waste Based Biorefinery: an Approach to Address Fuel, Waste Management and Sustainability. Biofuels, 395–404.
23. Kawashima, Tomoyuki., Davis, J., Luyckx, K. 2019. Surplus Food as Animal Feed. Access on 08

Desember 2019 from http://eu-refresh.org.

24. Kaza, S., Yao, L.C., Bhada-Tata, P., Van Woerden, F. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank, Washington, DC.
25. Kolekar, K.A., Hazra, T., Chakrabarty, S.N. 2016. A review on prediction of municipal solid waste generation models. Procedia Environmental Sciences, 35, 238–244.
26. Kristiningrum, S., Arianingrum, R., Sulastri, S. 2006. Pemanfaatan Limbah Kulit Ikan menjadi Kerupuk (Rambak). Jurnal Inovasi dan Teknologi (Inotek), 10(1), 13–25.
27. Kumar, S.J., Smith, S.R., Fowler, G., Velis, C. 2017. Challenges and opportunities associated with waste management in India. Royal Society Open Science, 4, 160764.
28. Kusumaningtyas, Ratna Dewi., Hartanto, D., Prasetiawan, H., et al. 2020. The Processing of Industrial Tofu Dreg Waste into Animal Feed in Sumurrejo Village Semarang. Rekayasa, 18(2), 36–41.
29. Limantara, J., Tedjokoesoemo, P.E.D.,, Rizqy, M.T. 2019. Penggunaan Ampas Kopi sebagai Material Alternatif pada Produk Interior. Jurnal INTRA, 7(2), 846–849.
30. Minghua, Z., Xiumin F., Rovetta, A., Qichang, H., Vicentini, F., Bingkai, L., Giusti, A., Yi, L. 2009. Municipal Solid Waste Management in Pudong New Area, China. Waste Management, 29, 1227–1233.
31. Muyani, Y. 2012. Pemanfaatan limbah sisik ikan kakap merah menjadi keripik sisik ikan kakap (Krisik Kakap). Jurnal Sains dan Terapan, 4(1), 65–72.
32. Nasir, M., Saputro, E.P., Handayani, S. 2015. Manajemen Pengelolaan Limbah Industri, 19(2), 143–149.
33. Ogwueleka, T.C. 2009. Municipal Solid Waste Characteristics and management in Nigeria. J. Environ. Health Sci. Eng, 6(3), 173–180.
34. Olukanni D.O., Akinyinka M.O., Ede A.N., Akinwumi I.I., Ajanaku K.O. 2014. Appraisal of municipal solid waste management, its effect and resource potential in a semi-urban city: A case study. Journal of South African Business Research, 13.
35. Peraturan Daerah Kota Padang No 21 Tahun 2012 tentang Pengelolaan Sampah.
36. Purnamasari, L., Pratiwi, N., dan Siswoyo, T.A. 2018. Teknologi pemanfaatan limbah padat pengolahan keripik singkong menjadi pakan pelet ayam pedaging di desa baratan kabupaten jember. Jurnal of Livestock Science and Production, 2(1), 79–85.
37. Putri, A.D., Zuhro, F., dan Habib, I.M.A. 2018. Analisis Gizi Limbah Ampas Kedelai sebagai Tepung Subtitusi Mie untuk Menunjang Sumber Belajar Mata Kuliah Biokimia. Jurnal Pendidikan Biologi dan Sains (BIOEDUSAINS), 1(1), 11–22.
38. Rahayu, L.H., Sudrajat, R.W., dan Rinihapsari, E. 2016. Teknologi Pembuatan Tepung Ampas Tahu untuk Produksi Aneka Makanan bagi Ibu-ibu Rumah Tangga di Kelurahan Gunungpati, Semarang. Jurnal Pengabdian Masyarakat, 7(1), 68–76.
39. Ruslinda, Y., dan Veronika. 2013. Satuan Timbulan dan Komposisi Sampah Industri Kota Padang. Jurnal Teknik Lingkungan Universitas Andalas, 10(1), 20–28.
40. Sugiura, K., Yamatani, S., Watahara, M., Onodera, T. 2009. Ecofeed, Animal Feed Produced from Recycled Food Waste. Veterinaria Italiana, 45(3), 397–404.
41. Syam, W.M. 2016. Optimalisasi kalsium karbonat dari cangkang telur untuk produksi pasta komposit. Skripsi sarjana ilmu sains jurusan kimia fakultas sains dan teknologi, UIN Alauddin Makassar.
42. Tchobanoglous, G., Teisen, H., Eliasen. 1993. Integrated Solid Waste Management, Mc.Graw Hill: Kogakusha, Ltd.
43. Tekler, Z. D., Low, R., Chung, S.Y., Low, J. S. C., Blessing, L. 2019. A Waste Management Behavioural Framework of Singapore's Food Manufacturing Industry using Factor Analysis. 26th CIRP Life Cycle Engineering (LCE) Conference Procedia CIRP, 80, 578–583.
44. Ulya, M., dan Hidayat, K. 2018. Identifikasi Peluang Produksi Bersih pada Industri Keripik Singkong. Reka Pangan, 12(1), 78–82.
45. Undang-Undang Republik Indonesia Nomor 18 Tahun 2008 Tentang Pengelolaan Sampah.
46. Upadhyay, V., Jethoo, A.S., Poonia, M.P. 2012. Solid waste collection and segregation: a case study of MNIT campus, Jaipur", International Journal of Energy Innovation Technology, 1, 144–149.
47. U.S. Environmental Protection Agency. 2014. A Guide to Conducting and Analyzing a Food Waste Assessment.
48. U.S. Environmental Protection Agency. 2016. Sustainable Management of Food: Food Recovery Hierarchy.
49. Waldron, K. 2007. Handbook of Waste Management and Co-Product Recovery in Food Processing Volume I. Cambridge England: Woodhead Publishing Limited and CRC Press LLC.
50. Widodo, E., Sjofjan, O., dan Wijaya, A.Z. 2010. Limbah Mie sebagai Pengganti Jagung dalam Pakan Ayam Pedaging dan Pengaruhnya terhadap Kualitas Karkas. Jurnal Ilmu dan Teknologi Hasil Ternak, 5(1), 38–44.
51. Yakin, E.A., Sukaryani, S., Purwati, C.S., Lestari, D. 2019. Addition of Tofu Waste to Concentrate Feed on Ruminant Animal Value. Bantara Journal of Animal Science, 1(2).
52. Yustina, I. 2011. Pemanfaatan Ampas Pengolahan Kedelai dalam Pembuatan Rengginang. Prosiding Seminar Hasil Penelitian Tanaman Aneka Kacang dan Umbi, 381–389.