5. DISCUSSION

5.1. Quantity of SUP Waste Generation

Fast food industry offers practical and time-efficiency for the consumers. There are another services provided by fast food restaurants, such as take away and drift-thru, so they can consume the products while on the go. However, all activities in fast food restaurants will generate SUP waste and this study is only focused on SUP waste generated by dine in consumers.

According to Aarnio & Hämäläinen (2008), fast food industries generate four packaging waste streams, including (1) transport packaging of sales packaging of food, (2) transport packaging of packed food and food raw materials, and (3) sales packaging of food. All these packaging are generated by the fast food outlet, while sales packaging of food is usually disposed at household level. The large numbers of sales packaging of food products produced from the dining area of the outlets and the rest of them are sales packaging of food that consumed outside the outlets.

Every item sold to the consumers contains waste. Most of the wastes generated by fast food restaurants, in this case FC1 and FC2, usually consists of SUP as food and beverages packaging, cutlery, etc. More SUP is generated in the weekends than weekdays by both FC1 and FC2, due to more visitors in the weekends. As expected the number of visitors is proportional to the food purchased, which will consequently increase the SUP generation.

This finding is similar with Raharjo et al. (2018) who found that in the weekends, the number of visitors in restaurants in Padang city is higher than in the weekdays. The weekends-weekdays gap of SUP generation is higher at FC1 than FC2, namely 43.3% and 25.8%, respectively. Differences of the number of visitors and sale volume led to higher SUP generation at FC1 than at FC2, both during weekdays and weekends. SUP wastes generated from FC1 also found higher than FC2. FC1 generate higher SUP about

wastes in weekdays, weekends, and the average of weekdays and weekends. FC1 generated 62.2% higher SUP wastes compared with FC2. Overall, FC1 generated more SUP waste than FC2 because of the differences in the number of visitors, where FC1 has more visitors compared with FC2.

All waste's polymer types were generated more in the weekends. Weekends generate higher SUP than weekdays because the products sold from both fast food restaurants are higher in weekend. According to Alfagi, Purnaweni, & Setiani (2015), fast food restaurants chains generated a lot of waste, with a significant increase of volume in the weekends. These wastes include plastic, paper, food and drink leftovers.

A study by Alfagi, Purnaweni, & Setiani (2015) distinguished waste as organic and inorganic. They found that KFC generated more inorganic waste rather than Pizza Hut, on the contrary the later discarded more organic. Inorganic and organic waste generation in KFC are 70% and 30%, respectively. While, Pizza Hut chains generates 40% and 60% inorganic and organic waste, respectively. Pizza Hut chains produced less inorganic waste because they used less plastic based items and utensils. Food waste is included in the category of organic waste, while fabric, rubber, paper, ferrous/non-ferrous metals, wood, glass, and plastic are included in the category of inorganic waste (Pertiwi *et al*., 2018).

According to Raharjo *et al*. (2018), plastic waste is the predominant waste generated by commercial facilities in Padang in 2016, followed by food waste, and paper waste. Whereas, in 2005 and 2009, the highest waste generated by commercial facilities in Padang is food waste followed by paper and plastic waste. However, in 2016, the generation of plastic waste is increased sharply, to surpass food waste. This indicates that for the past 10 years, the use of plastic, especially in Padang city increased significantly. For comparison, study in Semarang by Pertiwi et al., (2018) showed that the source of waste generation is dominated by household waste, about 75,5%, followed by market waste and industrial waste for about 14% and 4%, respectively.

The polymers of SUP used in FC1 and FC2 are PET, HDPE, PVC, LDPE, PP, PS, and LLDPE. In descending order, PP, PET, and LDPE are the most discharged polymers both by FC1 and FC2. Mackerron & Hoover (2015) reported that Mcdonald's uses 71% paper material for its packaging and followed by PP (13%). Similar to Mcdonald's, Starbuck also used paper (47%) as its main packaging, followed by PP (30%). Paper is also used as packaging material at FC2 and FC1. For packaging, paper is often combined with plastic; such as paper laminated with LDPE to improve moisture and gas barrier, and also to make it heat sealable (Coles et al., 2012; Raheem, 2013). LDPE also used in aseptic carton with other material, i.e. paper and aluminium. LDPE in aseptic carton has a role to prevents the food or beverages from making contact with the aluminium (Pasqualino et al., 2011). Paper in fast food restaurants typically used as food and beverages container.

LLDPE is the least plastic polymer contributing to SUP wastes in both fast food chains. LLDPE and PET are usually contained in metalized plastics, i.e. plastic laminated with a thin layer of aluminium metal (Pua et al., 2008). These films can improve the barrier properties to oil, air, moisture, and also scents. Besides that, they can also attract consumer's interest due to their highly reflective surface. Because it is a bit expensive, this package usually used for high values foods like herb and spice (Marsh & Bugusu, 2007). FC1 and FC2 rarely used metallized plastics in their food packaging.

5.2. SUP Waste Generation by Food Category

According to Aarnio & Hämäläinen (2008), fast food restaurants like FC1 and FC2 usually provide the same kind of menus or food products, which might fall into certain food categories. Some food categories generate higher SUP waste than the others. With refer to Rhodes et al. (2017), there are only 10 out of 15 food categories available at FC1 and FC2; namely condiments and sauces; grains; milk and dairy; mixed dishes; non-alcoholic beverages; protein foods; snacks and sweets; vegetables; water; and other.

Non-alcoholic beverages are the largest contributor of SUP waste, followed respectively by mixed dishes and snacks and sweets, and water at FC1; and mixed dishes, water, and snacks and sweets, at FC2. Non-alcoholic beverages packaging material is predominantly PP followed by PET, LDPE, PS, HDPE, and PVC (FC1); and PET, LDPE, HDPE and PVC (FC2). Non-alcoholic beverages is the most commonly purchased food category at FC1 and FC2, so the waste generated from this category is higher than other categories.

For mixed dishes category predominant packaging material is PP followed by LDPE, and PS (FC1); and mixed dishes category predominant packaging material is PP followed by (FC2). Snacks and sweets generated SUP waste including PET, LDPE, PP, and PS (FC1); and PET, PP, and PS (FC2); with PP is the largest in terms of weight in FC1 and PET in FC2.

In fast food restaurants, PP is mostly used for food containers, ice cream cup, and cold beverages cups (besides paper which is laminated with LDPE) (Mackerron & Hoover, 2015), and straw Pasqualino et al. (2011). PP is plastic polymer that significantly used besides paper, especially in non-alcoholic beverages, mixed dishes, and snacks and sweets category. The recycling markets for PP is still low and not yet as widespread as PET. It has been a challenge and responsibility to food service industry to increase the recycle opportunities because there is a gap between the used of PP in food service industry and the very low recycling rate (Mackerron & Hoover, 2015).

PET is typically found in cold cup lid and also in drinking bottle. PET also mainly used as bottle for mineral water and soft drink packaging (Pasqualino et al., 2011). Instead of food sales, beverage sales in both fast food restaurants are also high. Consumers go to fast food restaurants not only to buy food but also beverages. Moreover, there is a lot of consumers who visit fast food restaurants just to buy the beverages and to hangout. According to Mackerron & Hoover (2015), PET is plastic polymer that mostly used in food service industry as food and beverages container, especially fast food restaurant. However, the role of PET as food and beverages container has been replace with PP. PET is plastic material that mostly has been recycled. PS also polymers that commonly

used as cup lid as PET; however in fast food restaurants, PS likely used as cup lid for hot beverages.

For water category, SUP waste generated include PET, PVC, and HDPE are the major polymer used in water category; with PET is the typically waste generated in both fast food restaurants. HDPE and PVC are plastic polymers that only generated by two categories: water and non-alcoholic beverages. PVC usually used as sleeve labels for plastic bottles. The texts and images of the labels are printed on PVC film (Coles et al., 2012). Besides as plastic bags, HDPE usually used as screw caps (Boonstra, 2017). The more prevalent use of PVC and LDPE in water than non-alcoholic beverages due to the fact that water is mainly packaged in plastic bottles, while the later has more diversified packaging materials such as cup.

5.3. Carbon Footprint Generation

Carbon footprint per individual dine in consumer value is determined by number of visitor, types of polymer, and the packaging weights. In both FC1 and FC2, PP, LDPE, and PET are the top three polymer by weight. Accordingly the wastes of these three polymers constitute the largest carbon footprint and carbon footprint per individual dine in consumer. In FC1 PP is the largest contributor of carbon footprint followed by PET and LDPE. While in FC2 PET is the largest contributor of carbon footprint followed by PP and LDPE.

Weekdays generates higher carbon footprint per individual dine in consumer than weekends. FC1 and FC2 has more visitors in weekends rather than weekdays, therefore FC2 has higher carbon footprint per individual dine in consumer in weekdays than weekends. FC2 has higher carbon footprint per individual dine in consumer than FC1, due to the number of visitors in FC1 is higher than FC2. However, carbon footprint released by FC1 outlets is higher than FC2, so as weekends that have higher carbon footprint in FC1 and FC2, proportional with the weight of SUP generated in both fast food restaurants.

These differences can be explained by the different types of dishes, serving size, types of packaging provided by fast food chains. According to Franklin Associates (2011), PS releases the highest carbon dioxide emission rather than other plastic polymers. The order of plastic polymer that generates carbon dioxide emission from the highest to lowest are PS, PET, PVC, LDPE, LLDPE, HDPE, and PP. Mackerron & Hoover (2015) stated that PP produces 45% fewer greenhouse gas emissions compared with PET. Waste & Resources Action Programme (WRAP) (2008) stated that the weight of plastic may affects the raw materials used production energy required. Reduction of excess or unnecessary materials can reduce the weight of plastic and can reduce carbon footprint. In addition, Dormer et al. (2013) stated that reduce the weight of PET tray by 10%, 20%, and 30% can reduce carbon footprint respectively by 9.3%, 18.7%, and 29%.

According to Pasqualino et al. (2011) and Dormer et al. (2013), bottles made of glass has higher carbon footprint than plastic. Humbert, Rossi, Margni, Jolliet, & Loerincik (2009) also stated that baby food packed in PP has a lower carbon footprint than those of glass. In addition, Kling & Hough (2010) also stated that plastic packaging emitted lower amount of carbon footprint compared with paper, carton, steel can, and aluminium can.

In Semarang city, annually FC1 released 62,169.3 kg CO_2 eq generated from 7 outlets; and FC2 released 39,034.6 kg CO_2 eq generated from 11 outlets. FC1 emitted about one and half higher carbon footprint compared with FC2. In total, carbon footprint generated from both types of fast food chains contribute about 101 tons CO_2 eq in Semarang. However, the calculation was only based on SUP from packaging waste. According to Olivier & Peters (2018), carbon footprint generated in Indonesia is increasing in every year, while in 2017 about 0.51 giga tons CO_2 eq was released. In addition, Moran et al. (2018) stated that Semarang release 11.5 million ton CO_2 eq; which ranked 194th in global over 1300 others countries. Seoul generates highest carbon dioxide emissions in global, about 276.1 million ton, followed by Guangzhou, New York, and Hong Kong, respectively; 272.0, 233.5, 208.5 million tons CO_2 eq. Semarang is ranked as the 5th of city that contributes carbon footprint in Indonesia after Jakarta,

Yogyakarta, Surabaya, and Bandung which released respectively; 83.7, 19.0, 18.4 and 14.9 million ton CO_2 eq. So in comparison, SUP wastes generated at FC1 and FC2 haves contribute around $9E^{-6}$% total carbon footprint of Semarang.

According to Olivier & Peters (2018), Indonesia generates about 1.94 ton CO_2 eq carbon footprint per capita annually. In a year, FC1 and FC2 generates carbon dioxide emission from SUP packaging respectively 6.10 and 9.15 kg CO_2 eq per capita dine in consumer. Therefore, the comparison between SUP waste generated by both of fast food chains and carbon footprint per capita of Indonesian people are 0.003 and 0.005 %, respectively for FC1 and FC2.

In food related activities, each of Indonesian people releases carbon dioxide emission about 181.18 and 186.33 kg CO_2 eq in a year, respectively for animal and non-animal based product. Carbon footprint per capita released by food activities especially for animal based product in Indonesia is low compared with others country like Argentina, Australia, and Albania which are generate 2,140.65, 1,895.56, and 1,733.33 kg CO_2 eq in a year, respectively. However, Indonesia released higher carbon footprint per capita in food activities for non-animal based product rather than others country, although still lower than Bangladesh, Cambodia, and Vietnam which are generate 224.63, 208.28, and 200.70 kg CO_2 eq in a year, respectively. In total, annual carbon footprint released by food related activities including food waste in Indonesia is 367.51 CO_2 eq per capita (nu3, 2018). In comparison with carbon footprint generated from SUP waste by FC1 and FC2, food related activities emit higher carbon dioxide emission rather than SUP waste generated by FC1 and FC2. Hence, carbon footprint released by SUP waste generated from FC1 and FC2 are not predominantly contributed if compared with food related activities. Carbon footprint released by food related activities is still more dominating the carbon footprint per capita released by Indonesia people rather than SUP waste generated from FC1 and FC2.

Kling & Hough (2010) stated that packaging production (5%) release lower carbon footprint than food production (40%). Food production generates highest carbon footprint in USA followed with kitchen (15%), restaurants (14%), personal transportation (14%), supply chain transport (6%), packaging production (5%), retail (3%), and disposal (3%). In addition, Ourom (2014) stated that 152 million tonnes CO_2 eq is generated from activities related in food in UK. Farming and fishing generate 85.6 million tonnes CO_2 eq; whereas, another food activities associated with food industries starting from manufacturing until retail and preparation is 66.3 million tonnes CO_2 eq. Food storage, cooking, and manufacturing released higher carbon footprint about 19.5 million tonnes CO_2 eq, 15.4 million tonnes, and CO_2 eq, and 10.1 million tonnes CO_2 eq, respectively. However packaging only released 0.9 million tonnes CO_2 eq of carbon footprint, only 0.01% in comparison with all activities in food industries.

Referring to Kling & Hough (2010) and Ourom (2014), packaging seems not to be the major contributor of carbon footprint in food service sector like fast food chains. SUP packaging also generates carbon footprints, but not as much as food production, manufacturing, cooking, or food storage. However, SUP still a problem for the sustainability of our environment especially if accumulated in greater amount and being mismanaged (Giacovelli, 2018).

5.4. Carbon Footprint Generation by Food Category

From 10 categories of food stated by Rhodes et al. (2017), non-alcoholic beverages are a category of food contributing the largest carbon footprint per individual dine in consumer in FC1 and FC2; followed respectively by mixed dishes, snacks and sweets, and water (FC1); and water, mixed dishes, and snacks and sweets (FC2). Non-alcoholic beverages produced highest carbon footprint per individual dine in consumer followed respectively by mixed dishes and snacks and sweets, and water at FC1; and mixed dishes, water, and snacks and sweets, at FC2. Carbon footprint per individual dine in consumer produced by non-alcoholic beverages predominantly with PP followed by PET, LDPE, PS, HDPE, and PVC (FC1); and PET, LDPE, PVC, and HDPE (FC2). PET is plastic polymer that release the second highest carbon dioxide emission after PS.

Nevertheless, PP still plastic polymers that release carbon dioxide emission higher than PET in non-alcoholic category, because PP generates higher weight than PET in non-alcoholic beverages category.

Carbon footprint per individual dine in consumer released by water category are PET, PVC, and HDPE; with PET is the typically waste generated in both fast food restaurants. In term of weight, water category is the forth and third higher respectively in FC1 and FC2. However carbon footprint per individual dine in consumer of water category is the second higher and more higher than mixed dishes; while still remains in FC1. The carbon footprint per individual dine released by water category can exceed mixed dishes category because the weight of PP in mixed dishes category is lighter than PET in water category. According to, Mackerron & Hoover (2015) fast food industries used PET as food and cup container, however, nowadays they replace the use of PET to PP because PP produces lesser greenhouse gas emissions compared with PET. Mixed dishes category packaging material is predominantly PP followed by LDPE and PS (FC1); and PET and LDPE (FC2)

For snacks and sweets carbon footprint per individual dine in consumer constituted PP, PET, PS, and LDPE (FC1); and PET, PP, and PS (FC2); with PP is the largest polymers that released carbon footprint per individual dine in consumer in FC1 and PET in FC2. PP is the largest polymers which released higher carbon footprint per individual dine in consumer due to the weight of PP in FC1 is highest than PET, same as FC2 which has PET as the highest contribution of carbon footprint per individual dine in consumer.

According to Franklin Associates (2011), PP is a plastic polymer that releases the lowest carbon dioxide emission rather than other polymers such as PET, HDPE, PVC, LDPE, PS, and LLDPE. However carbon footprint per individual dine in consumer in FC1 is dominated with PP, especially for non-alcoholic beverages, mixed dishes, snacks and sweets, and protein food categories; and grains, mixed dishes, non-alcoholic beverages, and other category in FC2. Although PP releases lowest carbon dioxide emission, the use of PP in both of fast food restaurants is very high, so the weight generated by both fast food restaurants is also high.

5.5. Solution from Food Technology Perspective

Packaging has some important role in the food sector. Packaging is used to protect and to preserve food from contamination by unwanted objects and also to distribute food to the customer. According to Park et al., (2013), the most important issues in this century are global warming and sustainability. Therefore, the food and packaging industry is expected to be able to comply with global or regional regulations as well as consumer concerns regarding the number of packages being thrown away. Various terms such as eco, green, friendly, and environmental friendly are usually used to highlight the importance of sustainable development in the field of packaging in order to protect our environment in the future. In the development of product, design is the most important stage regarding to produces better quality, environmental outcomes, and consumer satisfaction.

The packaging design must fulfil several key functional requirements such as protection and sales promotion and also environmental friendly. To obtain eco-design methodologies, some principles must be fulfilled such as 3R, 4R, and 5R principles. 3R principles consist of reduce, reuse, and recycle. 4R principles consist of 3R principles added with recovery. 5R principles consist of 4R added with replacement using renewable or degraded resources. If the weight of packaging is reduced for source reduction, it must be done without compromising the safety and quality of package food (Park et al., 2013).

There are 4 food categories generating most of SUP based carbon footprint both in FC1 and FC2; i.e. non-alcoholic beverages, mixed dishes, snacks and sweets, and water. The responsible packaging polymers for the carbon footprints are PP (non-alcoholic beverages, mixed dishes, and snacks and sweets) and PET (water). Petroleum-based polymers such as PP and PET are widely used as food packaging material because of their high strength, durability, and stability. Those kinds of plastic also has long shelf life and very hard to degrade. It take many years to be degrade under normal condition because they highly resistant to chemical, microbial, and enzymatic reactions (Aung, et al., 2018).

Waste & Resources Action Programme (WRAP) (2008) said that light-weighting of SUP waste can significantly reduce carbon dioxide emission. Light-weighting can be done by reduce the size of the packaging or reduce the thickness of the packaging. According to Park et al., (2013), there is some guiding principle in order of doing reduction of packaging materials. Dormer et al. (2013) also said that recycled packaging can reduce carbon footprint emission. PET is packaging material than commonly recycled. However, besides light-weighting and recycle, the use of biopolymer such as poly-lactic acid (PLA) can be an option to produce more environmental friendly packaging. Nowadays, biopolymers began to be noticed and used as food packaging. Biopolymer has biodegradability and suitable for use as eco-friendly packaging. Biopolymers can be obtained from natural resources. Besides PLA, some examples of other biopolymers that are widely used are starch, cellulose, protein, polyhydroxyalkanoates (PHA), etc. In addition, Wu et al. (2016) said that PLA has lower carbon footprint in comparison with petroleum based polymer. Therefore, the use of biopolymers can be an option to be environmentally friendly packaging or eco-packaging.

Some advantages of PLA compared to other biopolymers according to Jamshidian et al., (2010) are including: the production of lactide monomer from lactic acid that is produces by corn which is a renewable agricultural source; highly energy savings; can be recycle again to lactic acid by hydrolysis; the ability to produce paper-plastic packaging mixture which is compostable; improve the agricultural economy; and the primary ability to adjust physical properties through modification of ingredients. PLA can be obtained from some agricultural products, such as corn, Jerusalem artichokes, beet molasses, wheat bran, sweet sorghum, cassava, barley starch, etc. The mechanical properties of PLA are similar to PET, however PLA has lower heat resistance than PET and poor heat resistant becomes a limitation of PLA packaging usage (Pang et al., 2010; Yang et al., 2010). PLA can be obtained by fermentation or chemically. In addition, to improve the properties of PLA, some modifications of crystallinity or nano-sized particles can be applied (Aung, et al., 2018).

According to Jamshidian et al. (2010), PLA is already applied as food packaging and commercially produced. PLA is generally recognized as safe (GRAS) by United State Food and Drug Administration (FDA) and safe for food packaging application. Some companies that actively involved in PLA manufacturing are PURAC Biomaterials, Cereplast, Stanelco, Biomer, Snamprogetti, Dai Nippon Printing Co., Mitsui Chemicals, etc. Previously, PLA packaging assumed to be only suitable for cold meals or beverages. However, nowadays PLA packaging problem towards heat can be resolved. Some companies like PURAC Biomaterials already commercialize PLA packaging which can be used for hot meals or beverages, can withstand temperatures of up to 120°C.

Based on the preliminary interviews it was found that consumers tend to prefer food with bigger packaging smaller food packaging, because bigger packaging usually contains larger portion of food. Some consumers also said that the thickness of packaging is important. Nevertheless, most of the consumers agree with bottle printing application, which can reduce the use of plastic labels. Whereas, the application of packaging light-weighting to reduce carbon emission might not be approved by some consumer except the application of bottle printing as long as the size of packaging is not reduced to be smaller or thinner than usual.

Most consumers also said that biodegradable packaging is considered to be more environmentally friendly than recycled packaging. However, most consumers assume that biodegradable packaging is more harmful to the environment compared to non-plastic packaging. Paper is the most non-plastic packaging that assumed to be environmentally friendly by the consumers. However consider to the carbon dioxide emission, paper releases higher carbon dioxide emission rather than plastic packaging, even paper packaging is more compostable than plastic packaging. Most consumers presume that paper packaging is more ease for being recycled. Whereas, biodegradable packaging such as PLA emitted lower carbon dioxide emission compared with plastic and paper packaging. Kogler (2012) also said that PLA is more easily degraded in the environment and more compostable compared to paper packaging.

Therefore, PLA packaging can be applied to replace SUP packaging in fast food restaurants like FC1 and FC2. PLA packaging is biodegradable, environmentally friendly, and emitted lowest carbon footprint compared with petroleum-based packaging which is currently used in fast food restaurants in Semarang. The replacement of PET packaging for plastic bottle and PP packaging for food container, ice cream cup container, and beverages container with PLA packaging can diminish the release of carbon footprint and can reduce the accumulation of plastic waste in fast food industry because PLA packaging can decompose easily in the environment.