Tampere University of Applied Sciences

Improving Sustainability of a Restaurant

A study on Sustainability of Different Takeaway Packaging Materials

Ngai Ching Linus Cheung

BACHELOR'S THESIS
June 2021

Energy and Environmental Engineering Degree Programme

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Energy and Environmental Engineering Degree Programme

NGAI CHING LINUS CHEUNG:
Improving Sustainability of a Restaurant:
A study on Sustainability of Different Takeaway Pack-aging Materials

Bachelor's thesis 39 pages, appendices 1 page
June 2021

In an era where people start to aware the damage that has been caused to the environment, the question of more sustainable and environmentally friendlier takeaway packaging material arises. The four most used packaging material up to date are paper/cardboard, plastic, metal and glass, in addition of the uprising biodegradable packaging.

The aim of the study was to find a suitable substitute material for the sushi boxes of the case study restaurant, ultimately improving its sustainability. In this study, comparisons between the different packaging were based on the three pillars of sustainability: social, economic and environmental. Through this process, a deeper understanding of the current trends and properties of the packaging materials and possible restrictions hindering them from being the sustainable and suitable packaging will be discovered. The study was conducted as a literature review.

The final result of the study shows that for a restaurant located in Finland, paper will currently be the best alternate option as to the plastic recycling in the country is scarce. As for the long run, due to its recent development and insufficient support, biodegradable materials may only deem a better solution as the technology and support for it advances. This will require much assistance from local government to set up proper industrial size composting and biodegrading facilities. Otherwise, it will only add to the current landfill and incineration problem. Yet, much more researching, studying and testing is necessary for a more precise comparison between the economic and environmental impacts for the packaging materials to obtain the perfect sustainable packaging.

Key words: paper, plastic, biodegradable, food packaging, takeaway, restaurant sustainability

CONTENTS

GLOSSARY or ABBREVIATIONS AND TERMS (choose one or other)

Cm	centimetre
CH_4	Methane
CO_2	Carbon Dioxide
EOL	End-of-Life
EPS	Expanded Polystyrene
H_2O	Water
LCA	Life-cycle assessment
mm	Millimetre
NGO	Non-Governmental Organization
OPS	Biaxially oriented polystyrene
Pcs	Pieces
PS	Polystyrene
UV	Ultraviolet
Ø	Diameter

1 INTRODUCTION

1.1 Overview

Restaurant takeaway services have been around for a while now where people are able to eat free from the boundaries of a restaurant. With the help of current communication technology, takeaway food has been made even easier with couriers delivering them right to your doorstep. This has been especially popularized during the last year due to the ongoing pandemic. (Yle Uutiset 2021; Das 2021; Leung & Magramo 2020)

However, convenience comes at a cost. The amount of waste that has been created by the takeaway packaging is horrendous. Plastic and paper bags, Styrofoam boxes, plastic cutleries; all disposable and single use, probably would be thrown away minutes after being used.

Though it is impossible to ask the entirety of humanity to step backwards and not taking advantage of the comfort of ordering from home and also using current packaging technology which keeps our food fresh and warm; yet there has not been any new methodology allowing the obsolescence of takeaway packaging. Hence, limiting and reducing the amount of waste would currently be the most optimal solution.

Apart from excessiveness, the materials used for the packaging is also a prominent factor that contributes to the overall pollution. The most notable packaging being paper and plastic, where the latter being more infamous for its destruction through longevity. Addition to the two, metal and glass packaging are also widely used as food packaging yet. And last there are biodegradable packaging, which are made of natural materials such as starch, mycelia, wheat, bamboo etc. (Chisenga et al. 2020)

Both paper and plastic have their advantages and disadvantages, while paper has been more popularly used recently due to its biodegradability and created from a renewable source. However, it is still debated which one does more overall

damage to the environment. As for biodegradable food packaging there are many varieties, and a lot are under research and development by customers' demand. Sadly, there are many confusing labelling and claims of the packaging's degradability only to satisfy the green customer.

1.2 Background

This thesis has been carried out due to several reasons. These reasons motivated me to study and continue this degree and in this field in hopes to improve the environment.

One of the reasons that motivated me to work on this topic is due to where and how I was brought up. Growing up in Hong Kong, plastic is a necessity, and it is unavoidable. From packaging of individual stationaries to a single strawberry, plastic is everywhere and cannot be removed from our lives. The usage of plastic is not a problem, however excessive usage of it is. Many of the excessive plastic are for decorative purposes and ends up in the bin along with the packaging as soon as they accomplished their purpose.

Although many Hong Kongers and Asians have relied on plastic to the degree of being inseparable, a handful of people and my family are aware of the waste it produces. Hence even without proper government support, I was brought up to recycling while many other around me are still strange to the concept.

PICTURE 1. Excessive Packaged Strawberry from Japan sold in Hong Kong (Knott 2017)

Another factor is due to an internships in an NGO in Hong Kong of which's main focus is dealing with local waste management problems. As mentioned before, Hong Kong people overly relies on plastic, additionally, Hong Kong has one of the worst recycling systems in the world. With only 3 recycling bins for paper, metal and plastic, it is hard enough to recycle things such as food waste and cartons. To add to this, without government support, there is a lack of local industrial scale recycling facilities, what is worse is that most of the recycled waste ends up in the landfill due to this fact.

Through my internship, I was able to further understand the existing problems within the Hong Kong waste management system, and though it is quite depressing to see how wasteful we are and how much the government is apathetic about environmental issues. Yet, I see the emergent need to fix the problem, hence my motivation to continue the on this path and study on this thesis topic.

1.3 Aim

The aim of this study is to compare the environmental friendliness between different takeaway packaging materials by looking through current research and trends. The results will then be analysed with consideration of the cost, and a new substitute packaging material for the restaurant will be suggested. This suggestion will act as a reference or future guideline for the case study restaurant in hopes of improving its overall sustainability.

2 CASE STUDY

The subject of this case study is a restaurant in Tampere Finland, a Finnish sushi restaurant franchise. As consent was not given by the restaurant to have their name published, they will be kept anonymous and will simply be known as the “SR” or “case study restaurant” in this report.

PICTURE 2. Sushi Takeaway Box (Yasitai n.d.)

Sushi restaurants are well known for their unique tray like takeaway boxes with a transparent lid. The case study SR is no different, using the exact same products other sushi restaurants would have, as seen in PICTURE 2 above. With the support from SR, statistical data of these takeaway sushi boxes ordered by SR were gathered and compiled in the TABLE 1 below. The raw data for this table is attached in Appendix 1.

The source of data (purchase quantity and prices for the products) used for this research are from 2019 as it is the only normal business data available due to the current pandemic situation.

TABLE 1. Product Information of Sushi Packaging Purchased by SR

	Item Picture	Item Amount (Pcs)	Material	Size (mm)	Selling Price	Cost (€)	Cost Per Piece
HP-05 Sushi Box		19400	Lid: OPS Base: PS	Lid: 186x129x30 Base: 185x128x20	€68/carton	3332	0.17
HP-07 Sushi Box		400		Lid: 217x137x30 Base: 216x135x20	€82/carton	82	0.21
HP-09 Sushi Box		300		Lid: 240x147x26 Base: 238x145x23	€82/carton	82	0.27
HP-11 Sushi Box		1850		Lid: 261.5x189x30, Base: 259x186.5x23.5	€90/carton	832.5	0.45
HP-65 Sushi Box		50		Lid: Ø383x16 Base: Ø381x47	€2.41/pcs	120.5	2.41

The table above shows the images, materials used, dimensions, selling prices for the products, the amount bought by SR for each product and their total value, how the products were sold to SR with their selling prices, and the cost for each piece of item for the products. The images of these products in the table were obtained from the website of the packaging supplier from which SR has patronized. Due to confidentiality, the name of the packaging supplier will not be referenced, yet the images are utilized with the packaging supplier's approval. Information of the products were also acquired from the packaging supplier's website.

3 METHODS

The research question of this study is “How to improve a restaurant’s sustainability by choice of food packaging?”

The research in this report was carried out by systematic investigation on takeaway food packaging materials, using a retrospective research plan through quantitative and qualitative research methods. These includes the case study data, content and statistical analysis and research etc. With literature review being the main methodology for this thesis.

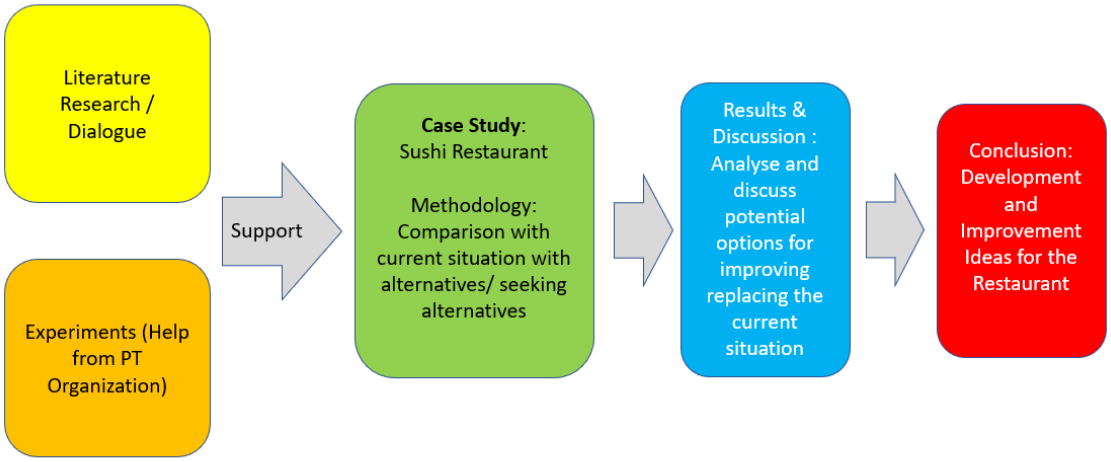


FIGURE 1. Thesis Mind Map made with Microsoft PowerPoint.

As the initial directives for this study was quite ambiguous and hard to keep track of, mind map as shown in FIGURE 1 and workflow chart were made with Microsoft PowerPoint to help clarify the objectives for this research and report. This also allowed easier navigation for seeking relevant sources.

Data and information of the packaging were obtained from the case study restaurant as mentioned in section 2 CASE STUDY above. These data are then utilized as reference for the comparison in the results.

Due to the vast number of sources and materials for topics regarding food packaging materials for the literature review, studies published more recently were adopted, information of different materials grouped together separately for easier comparison in the results section.

The grouping of literature review is based articles and journals investigating sustainability, cost, and benefits and drawbacks towards the environment and the restaurant and its customers of each of the studied packaging materials. These materials are grouped as followed:

- Plastics
    - PS
    - OPS
- Paper
- Biodegradable
    - Bioplastics and Biodegradable plastics
    - Bamboo
    - Leaves
    - Mushroom
- Others
    - Metal
    - Glass

The groupings will then be distributed in the results section into smaller sub-sections for easier comparison.

The main sources are from internet articles and news articles due to the limited number of scientific reports provided with the searched keywords. Attempts were made on ScienceDirect and Google Scholar, yet results that came back were either irrelevant, inconsistent or too detailed for this study. Hence, in order to confirm the factuality of these internet sources, multiple references were used on one reference to confirm, proof and verify its accuracy.

Although most sources are internet and news articles, yet some scientific articles were able to be found published by either packaging companies or environmental organizations, rarely by universities.

Sources picked from the internet are meticulously chosen unbiasedly from both sides, they were then analysed and used as comparison for a more diverse result to draw a well-rounded conclusion.

4 RESULTS AND DISCUSSION

In the following results, the basis for the comparison between the different types of food packaging are based on the strengths and weaknesses determined by their impacts on restaurants and its customers and impacts to the environment. The cost and EOL of the respective food packaging materials will also be looked at and compared. As the restaurant and its franchise is in Finland, the EOL of the materials compared will depend on the waste management and recycling systems existing in Finland.

PICTURE 3. Sushi Boxes with Labelling from Sushi Take-out, Hong Kong

In many cases, supermarkets or takeaway sushi restaurants will have nutritional labelling on the package as shown in PICTURE 3 above. However, in this study, these labels will be omitted as the sushi boxes are directly from the restaurant takeaway services which do not require and include such labelling. Hence, their impact on the environmental will not be accounted in the comparison. In addition, all packagings are assumed to be made without crossing over the other compared materials, combinations such as paper with plastic or metal lamination will either be left as inconclusive or not compared at all.

4.1 Plastic Packaging

Plastic has always been renowned for its lightweight, durability and low cost, and has been widely used in many industries for various purposes. There are 7 types of plastic and each of them have different properties, functions, as well as recyclability and sustainability. In the following table we will focus on comparing the properties of plastic used by the case study restaurant, PS, and OPS. A side note is that OPS is a variety of PS, though they share similarities they still have their differences.

TABLE 2. Strengths and Weaknesses of Plastic Packaging for the Restaurant and its Consumers and the Environment

	Strengths	Weaknesses
Restaurant and Consumers	▪ Long lasting ▪ Low cost ▪ High Durability ▪ Lightweight ▪ Versatile Usage ▪ Light ▪ Disposable, easy clean-up	▪ Not properly recycled. (Potential taxation charges) ▪ OPS is more fragile than other plastic due to being stretched to be transparent
Environment	▪ Recyclable (If done correctly) ▪ Reusable	▪ Long lasting ▪ Non-biodegradable ▪ Production produces large amount of greenhouse gases and carbon dioxide during production. ▪ Not properly recycled. ▪ Takes long period of time to decompose (~500-1000 years) ▪ Non-renewable ▪ Pollutes the environment (breaking down in to microplastic, toxifies soil when broken down by sunlight, chokes animals)

(Han et al. 2014, 15-16; Swiftpak 2021; FoodPrint n.d.)

Plastic is no doubt a go to packaging for many customers and restaurants. It has the finest qualities as a food packaging. Apart from being cheap, light and durable, it is also safe, odourless and has great barrier properties, making it hygienic to use as a food packaging material. Not to mention being disposable which saves time for many busy people from cleaning their dishes.

In addition to these perks, it also contributes a lot to the circular economy. Along their service life, plastics are extremely resource efficient and helps avoid food waste by keeping them fresh, saving energy, ultimately recuing CO_2 emissions. At their EOL, they can be repaired and reused. (PlasticsEurope 2017) Furthermore, they are recyclable and can be remade into new products after their EOL, if done correctly.

Although plastic has many perks, yet it is still harmful for the environment, from its non-renewable source to its long-lasting degrading properties, followed by the toxic it emits when it finally degrades, poisoning the soil and oceans. (Swiftpak 2021)

Though there is plastic recycling and is being promoted by world leaders, yet there are not enough recycling plants that could actually remediate or even reduce the harm done by plastic waste. In Finland, there is only one plant, Fortum's Riihimäki refinery that could recycle household plastic. Fortum has claim that in their best months of 2019, about 60-70% of household plastic gets recycled, (Aksela 2020) and 75% of the waste plastic gets recycled into new products. However, in reality only 37% of household plastic has been recycled in 2019 and the numbers have not changed much since then. (Miettinen 2021)

As for Europe, in 2018 the recycling rate of plastic waste was only 32.5% and 24.9% end up in the landfill. Luckily in a way, at least 42.5% of the plastic was recovered as energy, however this meant incineration of the plastic waste, which still emits much greenhouse gases in the process. (PlasticsEurope 2020) Alas, the global recycling of plastic waste is only 9%, which means 91% of global plastic waste is not recycled. (Parker 2019)

Plastic is only wreaking havoc on the environment and should not be used as disposable packaging. A reform on the packaging industry is necessary to conserve the environment.

4.2 Paper/Carboard Packaging

Along plastic, paper/cardboard has been the leading material used in the packaging history. Plastic has always been the favourable material as takeaway packaging due to its ability to hold fluid. However, paper/cardboard has recently been popular amongst the packaging industry due to the demands of end-consumers for more sustainable packaging. In the following table the pros and cons will be listed for paper as a packaging material.

TABLE 3. Strengths and Weaknesses of Paper/Cardboard Packaging for the Restaurant and its Consumers and the Environment

	Strengths	**Weaknesses**
Restaurant and Consumers	▪ Cost-effective ▪ Lightweight ▪ Rigidity ▪ Flexibility	▪ Less durable than plastic ▪ Not easy to stack. ▪ Damage by moisture.
Environment	▪ Recyclable ▪ Reusable ▪ Biodegradable ▪ Easy collection for recycling	▪ Cannot be recycled forever. ▪ Bigger carbon footprint than plastic during transport ▪ Contribute to deforestation. ▪ Feedstock is produced through mechanical or chemical process. ▪ Production mills uses a lot of energy and water.

(Han et al. 2014, 15-16; Swiftpak 2021; FoodPrint n.d.)

Paper/cardboard is almost as good of a packaging material as plastic in every way, from its cost to it versatile usage. It can also easily combine with other materials to improve its missing qualities, such as water resistance. The main difference is that paper/cardboard is produced from a renewable source, and it is biodegradable.

For restaurants and customers, paper/cardboard is definitely a lesser material than plastic in every way as plastic is sturdier than paper/cardboard. However, with environmental consciousness growing, many have turned to the renewable and biodegradable material instead. Some countries have even adopted paper/cardboard as a sushi packaging material as shown in PICTURE 4. Sadly, the packaging shown in the PICTURE 4 is believed to be laminated with plastic films, which is not the suggested solution.

PICTURE 4. Sushi takeaway from São Paulo, Brazil (Saki 2021)

Though paper/cardboard is generally a better option than plastic, it still has its downsides. Producing paper/cardboard creates 3.5 times more greenhouse gases than plastic, while manufacturing a paper bag uses 3.4 time the amount than a traditional plastic bag. (Emmerson Packaging 2019) Also, since mass production of paper products are required to satisfy the consumer's needs, it also contributes to deforestation.

As for recycling, paper/cardboard is a recyclable source and has a recycling rate of over 100% Finland in 2018. This number is due to the /cardboard packages imported by customers, online orders and effect of calculations of enterprises with lower turnover. Still, it shows that paper/cardboard is readily and steadily recycled

in Finland, in fact it is the most separately collected material in Finland. (Vertanen 2020)

Yet, paper/carboard eventually loses its integrity with each recycle and is said to be recycled for only 5 to 7 times before the fibres become too short to adhere to each other and create poor quality paper/carboard. (Swiftpak 2021) However, even if it loses its recyclability, it will eventually biodegrade after disposal.

Plastic VS Paper/Cardboard

Incredibly, when it comes to plastic verses paper there are polarized findings and results depending on the type of packaging. Still, most articles will start off by recognizing paper/cardboard is a more sustainable and environmentally friendlier material than plastic. (Swiftpak 2021; Emmerson Packaging 2019; Moreira 2020)

However, many plastic packaging companies will publish articles that suggests otherwise. They claim that if by comparing the LCA of plastics products, it is generally better than the LCA of paper products. Sadly, this is a very biased claim as these articles focuses only on the LCA but not the full process including the EOL of the products. There are also hard to measure criteria which do not end up in the LCA, such areas are like the constant flow of plastic that ends up end up in the ocean. Plastics lost from production or causation of animal death are hard to explain in graphs, which ends up omitted in the LCA. (Plastic Soup Foundation 2019)

It is true that plastic production has a better LCA than paper production due to the advance development of the industry due to the high customer demands. Yet, when comparing with their EOL, paper is in many ways more sustainable and environmentally friendly than plastic.

4.3 Biodegradable Packaging

The definition of biodegradable is the ability to naturally decay without harming the environment. (Cambridge Dictionary n.d.) As for biodegradable plastics, European standards EN 13432 declares that bioplastics and biodegradable plastics should be able to disintegrate at least 10% of its original material in piece bigger than 2mm after 12 weeks and should be 90% biodegraded in less than 6 months. (European Bioplastics 2016; youmatter 2020)

The biodegradable packaging discussed and compared in this section can be grouped into two main categories; synthesized materials, which includes bioplastics and biodegradable plastics; natural materials such as bamboo, mushroom and leaves. The following table will include all the advantages and disadvantages of all the materials mentioned above.

TABLE 4. Strengths and Weaknesses of Biodegradable Packaging for the Restaurant and its Consumers and the Environment

	Strengths	Weaknesses
Restaurant and Consumers	▪ Better reputation on environmental friendliness ▪ Improves brand image. ▪ Non-toxic, allergy free materials ▪ Strong, durable, mouldable ▪ Easily produced (Bamboo, mushroom) ▪ All properties of plastic except degradability (Bioplastic and biodegradable plastic) ▪ No health risk (Mushroom) ▪ Cheap to produce (Mushroom)	▪ Expensive to produce compared to plastic. Not as versatile as plastic (Bamboo, mushroom) • Longer to produce than plastic (Bamboo, mushroom, leaves) • Less variable and range of products to be produced compared to plastic (Bamboo, mushroom, leaves) • Not as fire resistance as PS (Mushroom)

Environment	▪ Less carbon footprints produced. ▪ Renewable ▪ Biodegradable and compostable. ▪ Less energy when manufactured. (Bioplastic and biodegradable plastic) ▪ No waste and pollution from production (Bamboo, mushroom, leaf) ▪ Synthesized in an energy efficient process (Bioplastic and biodegradable plastic) ▪ Upcycling (Mushroom) ▪ Re-purpose agricultural waste (Mushroom)	▪ Requires special conditions to compost or degrade. ▪ Lack of degrading and composting facilities

(Cho, Earth Institute, Columbia University 2017; Trvst 2019; Good Strat Packing n.d. Kaur 2020; Kushner 2021; Manning 2017; UrthPact 2018)

Biodegradable materials are no doubt the best option for takeaway packaging as they were manufactured due to popular demand of a sustainable substitute of plastic and paper/cardboard packaging. As for their EOL, all of the biodegradable packaging mentioned above are made to degrade in shorts periods of time (within a year) without harming the environment. If done properly, they will be the most sustainable option and could be the future of all packaging. Still, each of the materials has their own set of drawbacks.

Materials such as bamboos and leaves have been widely used in Asia before and are still in some street vendors. Considering their EOL and renewability, they are

the best option there is as takeaway food packaging as they are natural materials and can disintegrate naturally.

Bamboo

Widely used in Asia for construction, bamboo plants have also been used as a food containing material. Recently, bamboos have quickly become significant in the sustainable market due to its properties as an eco-friendly source. Commonly mistaken as a tree, bamboos are actually a type of grass will thousands of specie all over the world. Unlike trees which takes around 30 to 50 years to reach maturity for harvest, bamboos can grow up to 89 cm in a day and reach maturity within 3 to 5 years. (Good Strat Packing n.d.)

In addition to its abundance, they are also very durable, adaptable, cheap and versatile to produce. They are also naturally antifungal and antibacterial, which means less pesticides and fertilizers need to be used for their production and growth. (Trvst 2019)

There are two types of bamboo products; one is the more renowned, durable and reusable bamboo made for tableware and other tools like toothbrush and cups, which is made from the whole plant; the other being disposable packaging. As takeaway packaging is being discussed, the interest will be placed on the disposable ones. These are made from the part of the plant known as the sheath. The sheath will fall on the ground after reaching a certain age, the sheath is then collected, cleaned, boiled and then laminated. Once laminated, they will be pressed into the desired tableware shape. (Good Strat Packing n.d.)

Although disposable packaging made from bamboo seems to be the definite alternative. However, as mentioned above the sheath is laminated, and there is a lack of information on what laminating material is used. If plastic or any strong chemicals are used, then it beats the purpose. Hence, further study is required in order to draw a conclusive decision on whether disposable bamboo packaging is the suitable alternative.

Leaves

For leaf packaging, it has also always been used as food packaging in Asia, the types of leaves used may vary, but usually larger leaves such as bamboo leaves

and banana leaves have been used. Its quick natural deteriorating properties is great for the environment, on the contrary, this is not the case for restaurants and customers. However not all hope is lost for the material, in 2014 an Indian then has perfect cellular enhancement and has strengthen banana leaves to keep its properties for up to 4 years and then degrade naturally. (Hoeven 2019)

Still, leaves are comparably fragile and to have specific leaves mass produced and exploited is still not the best for the environment.

PICTURE 5. Banana Plate (Structural Packagingq 2010)

Mushroom

Mushroom is another material currently being used to produce packaging that replaces the very formidable polystyrene, also known as Styrofoam. To be more specific, the part of the fugus in use is the mycelium also called “nature’s glue” as it the fugus uses theses long strands to attach itself to other structures. (Manning 2017; Ecobahn 2020)

The procedure for creating this PS substitute also uses organic materials such as agricultural waste and hemp where upcycling is done. First, these organic materials are pasteurized and diced. Then nutrients, water and pellet form mycelium are added into the mixture. Finally, the mixture is sealed in a packaging mould and hidden from light. Between 3 to 5 days, the mycelium will grow into the shape of the mould. The product is then cooked to stop the growth of the mycelium. (Manning 2017)

The finishing product will have the same properties, function and cost of EPS with the new benefit of compostable and biodegradable shown in PICTURE 6.

PICTURE 6. MycoFoam Product made from Mycelium (Ecovative n.d.)

As PS is widely used as takeaway food container due to its cheap cost, light weight and heat trapping properties. This substitute for PS would be perfect as a takeaway packaging, especially for this case study where PS is used for the sushi boxes. However, due to the lack of information and limited showcasing, it was unknown whether these MycoFoams are usable for directly containing food like PS boxes. As some fungi are toxic to the human body, it is not sure if the MycoFoams could be a replacement of current PS takeaway boxes and trays, further study on the material is required to draw a safe conclusion.

Bioplastics and Biodegradable plastics

Directly from the name, it can be known that these plastics are biodegradable. There are 5 main types of bioplastics, these include starch-based made from corn-starch and is usually mixed with biodegradable polyesters; cellulose-based

made from cellulose esters and cellulose derivatives; protein-based made from protein source such as wheat gluten, casein, and milk; aliphatic polyesters, a group of biobased polyesters including polyhydroxyalkanoates (PLAs), poly-3-hydroxybutyrate (PHB), polyhydroxyvalerate (PHV) and polyhydroxyhexanoate (PHH) etc; and finally organic polyethylene made form fermented raw agricultural materials like sugar cane and corn.

Bioplastics are a complicate topic to discuss due to ongoing scientific research and political debates. It is still debated whether bioplastics are actually more sustainable and environmentally friendlier than traditional plastic.

Although bioplastics and biodegradable plastics are biodegradable and compostable, they require specific conditions like existing microorganisms such as bacteria, fungi, and algae in the soil, high temperature UV light, and oxygen to biodegrade into H_2O, CO_2, CH_4, biomass and inorganic compounds. (UrthPact 2018) Whereas landfills have no oxygen which means bioplastics will not degrade in landfills (Grabianowski n.d.)

Even if it biodegrades, another factor worries people is that these bioplastics will degrade into CH_4 which is a more harmful greenhouse gas than CO_2 which, ultimately contributing to and accelerating climate change. (Grabianowski n.d.)

Apart from the pollution due to the incorrect disposal, it is said that the bioplastics release more pollutant due to the number of pesticides and fertilizers used for growing the raw materials such as corn and sugar canes. As well as the chemical process needed to turn organic materials to plastic. (Grabianowski n.d.; Cho, Earth Institute, Columbia University 2017)

Apart from the distressing concerns, its ground-breaking technology comes with a cost, it is said that bioplastics are 20%-100% more expensive to produce than traditional plastic, this will be a major concern for the restaurants. (Grabianowski n.d.; Cho, Earth Institute, Columbia University 2017) However, as the technology advances, the cost may reduce due to stable supply of production equipment amount. Hence, the cost will not be a deciding factor for now when it comes to bioplastic.

Though there are many concerning facts about bioplastic, yet it is still created from a renewable source and can replace the use of limited fossil fuels, it also

reduces the amount of waste going to landfills and incineration if disposed correctly.

Bioplastics and biodegradable plastics are still rather new and unpopularized with many complications, such as suitable facilities and conditions for them to properly biodegrade. (Oakes 2019) Also, due to its new status, many people often accidentally recycle them like normal plastic, where they should actually be recycled separately in a different stream. (Bioplastics guide n.d.)

Furthermore, in order to satisfy the green consumers on the market, many confusing labelling exists, such as the oxo-biodegradable plastic which is still being debated on their impact on the environment by turn into microplastic instead of fully degrading. (Goldsberry 2019) Due to all the uncertainty, all bioplastics and biodegradable plastics. Further study and research are required in order to understand their properties for comparison and consideration.

4.4 Other Packaging

The following two food packaging, glass and metal has been widely used as food packaging before the discovery of plastic and it is still in use today. However, they are mainly used for packaging pre-packed, preserved food or beverages instead of takeaway food. And since the discovery of plastic, they have slowly become obsolete as market food packaging. (Blackburn 2016)

Although they are very durable and more sustainable compared to plastic and paper/cardboard, (Tinware Direct n.d.; Metal Packaging Europe n.d.) they are not suitable and will not be considered as the alternate takeaway packaging for this case. Yet it is still worth showing these alternatives as they are still a viable option and will be the most sustainable option compared to all the above if done properly.

To further understand the situation, the following tables below will show the pros and cons of the two packaging materials regarding the restaurant industry and the environment.

4.4.1 Metals

TABLE 5. Strengths and Weaknesses of Metal Packaging for the Restaurant and its Consumers and the Environment

	Strengths	**Weaknesses**
Restaurant and Consumers	▪ Durability ▪ Sturdy Storage ▪ Wide variety ▪ Excellent barrier, protection properties ▪ Ductility ▪ Generally, meets hygiene and safety requirements.	▪ Heavy ▪ Susceptible to corrosion ▪ Acid and alkaline resistance is weak. ▪ Easily rust. ▪ Expensive compared to most packaging
Environment	▪ Reusability ▪ Recycles forever. ▪ Permanent resource. ▪ Natural elements ▪ Susutainable	▪ Energy intensive production ▪ Creates toxic sludge which has radioactive and heavy metal elements during production. ▪ Creates emission such as greenhouse gases, sulphur dioxide, dust, polycyclic aromatic hydrocarbons and wastewater during production.

(Tinware Direct n.d., 1.; Container Exchanger n.d.; Grandroad n.d.; FoodPrint n.d.)

The impact of metals on the environment is mainly through the extraction and production process which requires in-depth study to further understand the situations for a more precise and fair comparison with the LCA of plastic and paper/cardboard packaging.

Many studies have suggested that metals are the most recycled packaging material ever and about 80% of the metals ever produced are still in use today, with 79.5% recycling rate in Europe. Achieving circular economy and hence making metal one of the more sustainable materials as a packaging. (Tinware Direct n.d., 2.; Metal Packaging Europe n.d.)

Although there are many perks for metal due to its reusability and infinite recyclability with no loss to their inherit properties, the deciding factor for it to be a takeaway packing is its cost and weight.

For a restaurant, it will be unreasonably costly to provide disposable metal packaging for each and every customer as a takeaway box. Additionally, it will take much effort and re-educating to have customers bring their own reusable container for takeaway food, which will be a revolution in the restaurant industry, not to mention the complications with food delivery services. Besides, customers will not be willing to take such heavy packaging just for a meal.

4.4.2 Glass

TABLE 6. Strengths and Weaknesses of Glass Packaging for the Restaurant and its Consumers and the Environment

	Strengths	Weaknesses
Restaurant and Consumers	▪ Non-porous and non-toxic surface ▪ Retains true flavour of foods. ▪ Better sustainability for carbonation.	▪ Heavy ▪ Fragile ▪ Costly
Environment	▪ Fully recyclable (if done properly) ▪ Sustainable ▪ Made with natural elements.	▪ Raw material is burnt by fossil fuel. ▪ Combustion of feedstock material creates emissions such as greenhouse gases, sulphur oxides and nitrogen oxides. ▪ Raw material emissions through recrystallization and vaporization may include fine particulates containing heavy metals like arsenic and lead. ▪ Larger carbon footprint compared to plastic production due to ample amount of heat and highly energy intensive.

(FoodPrint n.d.; Tinware Direct n.d., 2; Sarkina 2020; Dube 2020)

Similar to metal, the main source of impact on the environment of glass is through the production phase, which requires further study to fully understand the circumstances for a more accurate and fair comparison.

Like metal, glass is 100% recyclable and is very sustainable once produced and enters the circular economy. Yet, the production phase of the packaging material

creates more carbon footprints than that of producing plastic. In addition to that, only around 34% of glass containers enter the recycling stream. (Sarkina 2020)

Another similarity with metal is that the deciding factor for it as a takeaway packaging comes down to its cost and weight. Additionally, the fragility is also considered for glass packaging. No doubt, glass is too expensive and heavy as a takeaway packaging; combined with being fragile, it can get hazardous if broken during transport of the food.

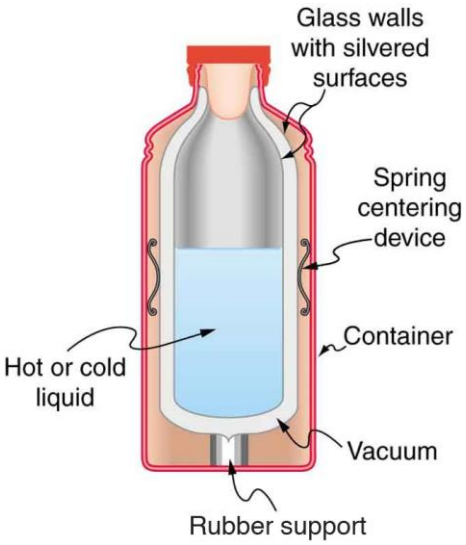
4.4.3 Glass and Metal Takeaway Packaging

An interesting fact is, metal and glass had been used as a takeaway tool at certain points in history, however the format differs from the current disposable ones. Instead, it is a reusable thermal container where people will bring along with them when they are planning to get takeaway. This is portrayed in a scene from the 2000 Hong Kong movie “In the mood for love”.

In one of the scenes, a thermal container was brought by the main actress to a street vendor for takeaway food where it gets filled with food by the street vendor and the main actress bring it home to eat. The movie takes reference from lifestyles in the 60s of Hong Kong, which shows that people once used metal containers to do takeaway. (In the Mood for Love 2000)

The technology and of this type of thermal container dates back to 1892 when Vacuum Flask was discovered by a Scottish Scientist Sir James Dewar. It was then adapted in 1903 by the Scottish Scientist’s scientific glass device manufacturers, Reinhold Burger and Albert Aschenbrenner and created the vacuumed thermal bottles known today. (Thermos n.d)

The brilliance of the technology is mainly with the vacuum glass in it, as vacuum contains no atoms, heat cannot be conducted through a vacuumed glass theoretically. Hence, the main way to trap heat is to have a vacuumed glass covered in silver glass to reduce infrared radiation, and have it surrounded by a metal casing to keep the heat from dispersing, as shown in PICTURE 10 below. (Thermal Facts 2015) Keeping the content inside fresh and warm or cold for the duration of delivery until consumption.



PICTURE 10. Inner workings of Thermal Container (Thermal Facts 2015)

Unfortunately, this seems to be the only recorded usage of metal and glass material as takeaway food packaging.

5 CONCLUSION

Plastic waste is no doubt a major culprit on damaging and polluting our environment. Though they were made for the convenience and comfort for humanity, they were advertised as single use by enterprises causing the plastic crisis we know today. Now we have a long way to clean up this mess and hopefully protect what remains from this plastic warfare. This research attempts to analyse the properties of different packaging through their impact on society and economy, and the environment.

Due to a lack of information and published studies, inconsistent comparison through different scientific articles, and new packaging materials still under observation, the LCA of each packaging material could not be precisely compared. Also, even with the detailed information provided by the case study restaurant, with the lack of information on the cost of the alternative packaging materials, they cannot be compared directly as intended. Hence, this study can conclude with the limited statistical data found and presented in the results. Further study and practical research are needed in order to have a more precise comparison.

To conclude, based on all the results, unlaminated paper/cardboard would currently be the most optimal and sustainable takeaway packaging material for the case study restaurant. This is with consideration of the food item and lifespan of the takeaway packaging. Sushi is generally not a moist food item, and considering the raw fish, sushi is meant to be devoured as soon as possible, making the time of it being in a takeaway packaging very short. Although paper/carboard is less durable than plastic, still with these considerations, plastic lamination may not be needed, allowing the paper packaging fully recyclable and biodegradable after use.

In addition, as paper/cardboard recycling in Finland is done so skilfully and almost flawlessly, paper can be easily recycled. Plus, with its biodegradability, paper/cardboard would be the better choice.

However, in the long run, as technology advances paper/cardboard may become obsolete due the heavy pollution done during production and contribution to global deforestation. Instead, biodegradable materials such as bamboos and

mushrooms maybe even leaves would be a better material for packaging. As for bioplastics, it is still under development and observation, more research and studies are required in order to understand its full impact on the environment. In addition, bioplastic will require a lot of support from governments for installing industrial size composting and biodegrading facilities, allowing bioplastics to biodegrade as intended without poisoning the environment.

All in all, in this warfare of the more sustainable packaging material, the best solution to this problem is to use fewer disposable products. Instead, reusing containers made of any material will help with the environment by reducing the excessive waste and trash created.

REFERENCES

Aksela, M. 2020. Plastic recycling: The consumer does the sorting; Suomen Uusiomuovi Oy does the recycling!. Internet Article. Published on 14.08.2020. Read on 04.06.2020. https://woodly.com/plastic_and_environment/plastic-recycling-the-consumer-does-the-sorting-suomen-uusiomuovi-oy-does-the-recycling/#:~:text=Fortum's%20Riihim%C3%A4ki%20refinery%20is%20currently,through%20recycling%2C%20as%20new%20products.

Blackburn, M. 2016. One Brown Planet. Life Before Plastic. Published on 28.05.2016. Internet Article. Read on 27.05.2021. https://www.onebrownplanet.com/life_before_plastic/

Bioplastics guide. n.d. Bioplastics – End-of-life options. Guide. Read on 01.06.2021. http://www.bioplastics.guide/ref/bioplastics/end-of-life-options#:~:text=Bioplastics%20can%20be%20recycled%20but,material%20it%20is%20mixed%20with.

Cambridge Dictionary n.d. Meaning of biodegradable in English. Definition. Read on 01.06.2021. https://dictionary.cambridge.org/dictionary/english/biodegradable

Chisenga, S. M., Tolesa, G. N. & Workneh, T. S. 2020. Biodegradable Food Packaging Materials and Prospects of the Fourth Industrial Revolution for Tomato Fruit and Product Handling. Review Article. Published on 23.11.2020. Read on 07.02.2021. https://www.hindawi.com/journals/ijfs/2020/8879101/

Cho, R. Earth Institute, Columbia University. 2017. The truth about bioplastics. Research Article. Published on 14.12.2017. Read on 01.06.2021. https://phys.org/news/2017-12-truth-bioplastics.html

Container Exchanger. n.d. The Advantages and Disadvantages to Metal Packaging. Blog Post. Read on 30.05.2021. https://blog.containerexchanger.com/the-advantages-and-disadvantages-to-metal-packaging/

Das, D. European Supermarket Magazine. 2021. Finland's R-kioski Expands Food Home Delivery with Foodora. News Article. Published on 21.05.2021. Read on 26.05.2021. https://www.esmmagazine.com/retail/finlands-r-kioski-expands-food-home-delivery-foodora-133554

Dube, N. 2020. Flexible Packaging VS Glass Packaging: Pros And Cons. Blog Post. Published on 06.02.2020. Read on 31.05.2021. https://www.industrialpackaging.com/blog/flexible-packaging-vs-glass-packaging-pros-and-cons

Ecobahn. 2020. Sustainable Mushroom Packaging: The Magical Mushroom Company. Internet Article. Published on 21.09.2020. Read on 01.06.2021. https://theecobahn.com/packaging/sustainable-mushroom-packaging-the-magical-mushroom-company/

Emmerson Packaging. 2019. Paper Vs. Plastic Packaging. Which is More Environmentally Friendly?. Blog Post. Published on 28.05.2019. Read on 23.05.2021. https://www.emmersonpackaging.com/2019/05/28/paper-vs-plastic/

European Bioplastics. 2016. What are the required circumstances for a compostable product to compost?. FAQ Forum. Published on 02.03.2016. Read on 01.06.2021. https://www.european-bioplastics.org/faq-items/what-are-the-required-circumstances-for-a-compostable-product-to-compost/#:~:text=The%20criteria%20for%20the%20industrial,have%20been%20converted%20to%20CO2.

FoodPrint. n.d. The Environmental Impact of Food Packaging. Research Article. Read on 30.05.2021. https://foodprint.org/issues/the-environmental-impact-of-food-packaging/#:~:text=Each%20form%20of%20packaging%20uses,or%20sludge%20containing%20toxic%20contaminants.

Grandroad. n.d. What are the advantages and disadvantages of using metal packaging materials? News Article. Read on 30.05.2021. http://en.grandroad.com.cn/news/1.html

Goldsberry, C. Plastics Today. 2019. Industry association strikes back at proposed EU ban on oxo-degradable plastics. News Article. Published on 01.04.2019. Read on 01.06.2021. https://www.plasticstoday.com/sustainability/industry-association-strikes-back-proposed-eu-ban-oxo-degradable-plastics

Good Strat Packing. n.d. Guide to Bamboo Packaging. Guide. Read on 01.06.2021. https://www.goodstartpackaging.com/guide-to-bamboo-packaging/

Han, J. H., Kim, Y. T., Min, B. & Kim, K. W. 2014. Innovations in Food Packaging. General Characteristics of Packaging Materials for Food System. 2nd Edition. USA: Elsevier

Hoeven, D. v. d. 2019. Processed banana leaves, an eco-friendly packaging solution. Internet Article. Published on 19.09.2019. Read on 01.06.2021. https://www.biobasedpress.eu/2019/09/processed-banana-leaves-an-eco-friendly-packaging-solution/#:~:text=In%20Asia%2C%20banana%20leaves%20were,it%20properties%20for%20three%20years.

In the Mood for Love. 2000. Director: Kar-wai Wong. Production: Jet Tone Production, Paradis Films. Production Countries: Hong Kong, China.

Kaur, M. 2020. THE PROS AND CONS OF ECO-FRIENDLY PACKAGING. Internet Article. Published on 19.11.2020. Read on 01.06.2021. https://lekac.com/production/the-pros-and-cons-of-eco-friendly-packaging

Knott, K. SCMP. 2017. Hong Kong supermarket selling strawberries individually wrapped for HK$168 as pressure grows to reduce packaging. News Article. Published on 23.11.2017. Read on 15.05.2021. https://www.scmp.com/lifestyle/food-drink/article/2068813/hong-kong-supermarket-selling-strawberries-individually-wrapped

Kushner, J. 2021. Corn Starch Plastic – The 7 Advantages and Disadvantages of its Use. Internet Article. Published on 22.04.2021. Read on 01.06.2021. http://www.bionomicfuel.com/corn-starch-plastic-the-advantages-and-disadvantages/

Leung, K. & Magramo. K. SCMP. 2020. A tip is nice, but ‘thank you’ goes a long way for Hong Kong’s growing army of food delivery workers. News Article. Published on 05.09.2020. Read on 26.05.2021. https://www.scmp.com/news/hong-kong/hong-kong-economy/article/3100360/tip-nice-thank-you-goes-long-way-hong-kongs

Manning, A. 2017. Mushrooms: An Ecological Alternative to Plastics?. Research Article. Published on 10.10.2017. Read on 01.06.2021. https://www.greenbatch.com/blog/2017/10/10/mushrooms-an-ecological-alternative-to-plastics

Metal Packaging Europe. n.d. Sustainability. Internet Article. Read on 30.05.2021. https://metalpackagingeurope.org/sustainability#smooth-scroll-top

Miettinen, L. 2021. Suurin osa kodeissa lajitellusta muovijätteestä päätyi poltettavaksi – MOT selvitti, kuinka hyvin muovin kierrätys onnistuu. News Article. Published on 05.04.2021. Read on 04.06.2021. https://yle.fi/uutiset/3-11865230

Moreira, M. S. Wood Mackenzie. 2020. Is Paper A More Sustainable Flexible Packaging Material Than Plastic?. News Article. Published on 24.08.2020. Read on 24.05.2021. https://www.forbes.com/sites/woodmackenzie/2020/08/24/is-paper-a-more-sustainable-flexible-packaging-material-than-plastic/?sh=417a802012d4

Oakes, K. BBC. 2019. "Green" alternatives to throwaway plastics don't always break down in sea water. But could they help to fix our food waste problem?. News Article. Published on 05.11.2019. Read on 01.06.2021. https://www.bbc.com/future/article/20191030-why-biodegradables-wont-solve-the-plastic-crisis

Parker, L. National Geographic Society. 2019. A Whopping 91 Percent of Plastic Isn't Recycled. News Article. Published on 05.07.2019. Read on 04.06.2021. https://www.nationalgeographic.org/article/whopping-91-percent-plastic-isnt-recycled/

PlasticsEurope. 2017. An analysis of European plastics production, demand and waste data. Plastics – the Facts 2017. Presentation. Read on 31.05.2021. https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf

PlasticsEurope. 2020. An analysis of European plastics production, demand and waste data. Plastics – the Facts 2020. Presentation. Read on 04.06.2021. https://www.plasticseurope.org/en/resources/publications/4312-plastics-facts-2020

Plastic Soup Foundation. 2019. THE PLASTIC INDUSTRY ABUSES LIFECYCLE ANALYSIS (LCA) IN COMMUNICATION SURROUNDING PLASTIC POLLUTION. News Article. Published on 16.10.2019. Read on 03.06.2021. https://www.plasticsoupfoundation.org/en/2019/10/the-plastic-industry-abuses-

lifecycle-analysis-lca-in-communication-surrounding-plastic-pollution/#:~:text=The%20LCA%20is%20based%20on,and%20climate%20impact%20are%20considered.&text=It%20is%20convenient%20for%20the,a%20product's%20life%20into%20account.

Sarkina. 2020. Glass Packaging: The Pros And Cons. Published on 23.03.2020. Blog Post. Read on 31.05.2021. https://www.sarkina.com/blog/post/glass-packaging-pros-and-cons

Structural Packaging. 2019. Banana leaves: Food packaging revolution. Published on 30.09.2019. Blog Post. Read on 01.06.2021. http://structuralpackagingblog.com/en/banana-leaves-food-packaging-revolution/

Swiftpak. 2021. Plastic vs Paper Packaging: The Pros and Cons. Internet Article. Published on 12.04.2021. Read on 23.05.2021. https://www.swiftpak.co.uk/insights/plastic-vs-paper-packaging-the-pros-and-cons

Thermal Facts. 2015. How Does a Thermos Work?. Facts. Updated on 27.10.2015. Read on 30.05.2021. https://www.thermosfacts.com/how-does-a-thermos-work-2/

Thermos n.d. HISTORY OF THERMOS. Timeline.nRead on 30.05.2021. https://www.thermos.com/history#:~:text=In%201892%2C%20Scottish%20scientist%20Sir,between%20the%20two%20bottle%20walls.

Tinware Direct n.d. 1. Advantages of Metal over Plastic Packaging. Internet Article. Read on 30.05.2021. https://tinwaredirect.com/blogs/tips-advice/advantages-of-metal-over-plastic-packaging

Tinware Direct n.d. 2. Environmental Impact Of Plastic Vs Metal. Internet Article. Read on 30.05.2021. https://tinwaredirect.com/blogs/tips-advice/environmental-impacts-of-plastics-vs-metals

Trvst. 2019. Bamboo Versus Plastic... Is Bamboo Really More Eco-Friendly?. Research Article. Published on 26.09.2019. Read on 01.06.2021. https://www.trvst.world/sustainable-living/bamboo/bamboo-versus-plastic-is-bamboo-really-more-eco-friendly/

UrthPact. 2018. The Basics of Bioplastics. Internet Article. Published on 29.03.2018. Read on 05.06.2021. https://www.urthpact.com/bioplastics-basics/

Vertanen, V. 2020. More municipal waste was generated in 2018 than in previous years. Statistical Article. Published on 15.01.2020. Updated on 17.01.2020. Read on 05.06.2021 https://www.stat.fi/til/jate/2018/jate_2018_2020-01-15_tie_001_en.html

Yle Uutiset. 2021. Wednesday's papers: Pandemic polling, takeaway tensions, prime property. News Article. Published on 17.03.2021. Updated on 18.03.2021 Read on 26.05.2021. https://yle.fi/uutiset/osasto/news/wednesdays_papers_pandemic_polling_takeaway_tensions_prime_property/11840760

Youmatter. 2020. Biodegradable (Plastic) Definition. Definition. Updated on 21.01.2020. Read on 01.06.2021. https://youmatter.world/en/definition/biodegradable-plastic/

APPENDICES

Appendix 1. Raw Data of Number of Purchased Takeaway Boxes from Case Study Restaurant

	总计 (Total)	单位 (Unit)
总计 (Total)	400	
[DG4045] HP-05 Sushi Box (Maple leaf) 50sets/Bag | HP-05 寿司外卖盒(枫叶) 8包/箱	**41**	箱 (Carton)
28 3月 2019	1	箱 (Carton)
04 4月 2019	8	箱 (Carton)
18 4月 2019	8	箱 (Carton)
16 5月 2019	8	箱 (Carton)
12 9月 2019	8	箱 (Carton)
19 9月 2019	8	箱 (Carton)
[DG4046] HP-07 Sushi Box（Maple leaf） 50sets/Bag | HP-07 寿司外卖盒(枫叶） 50套 / 包	**8**	包 (Bag)
16 8月 2019	8	包 (Bag)
[DG4047] HP-09 Sushi Box (Maple leaf) 50sets/Bag | HP-09 寿司外卖盒(枫叶） 50套 / 包	**6**	包 (Bag)
17 10月 2019	6	包 (Bag)
[DG4048] HP-11 Sushi Box（Maple leaf） 50sets/Bag | HP-11 寿司外卖盒(枫叶）50套 / 包	**37**	包 (Bag)
03 1月 2019	4	包 (Bag)
24 1月 2019	4	包 (Bag)
28 3月 2019	1	包 (Bag)
04 4月 2019	4	包 (Bag)
18 4月 2019	4	包 (Bag)
19 8月 2019	8	包 (Bag)
29 8月 2019	4	包 (Bag)
03 10月 2019	4	包 (Bag)
17 10月 2019	4	包 (Bag)
[DG4049] HP-65 Party Sushi Box (Maple leaf) | HP-65 寿司圆形外卖盒(枫叶） / 个	**50**	个 (Pcs)
03 1月 2019	10	个 (Pcs)
14 2月 2019	10	个 (Pcs)
28 2月 2019	20	个 (Pcs)
04 4月 2019	10	个 (Pcs)
[DG4060] HP-05 Sushi Box (Black) 400 sets/CTN | HP-05 寿司外卖盒(黑色底）400套 / 箱	**8**	箱 (Carton)
16 8月 2019	8	箱 (Carton)