

The Creation of Single-Use Packaging from Leaves

to Reduce Plastic Waste in Thailand

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Abstract

This research aims to analyze design criteria for creating single-use packaging from leaves to reduce plastic bag waste generated by street food and T-shirt purchases along with evaluating tools for producing these biodegradable packages. *Design Thinking* was utilized as a conceptual research framework. The research covered consumers, street food vendors and packaging producers. Observations and interview forms were used to collect data on the characteristics of different leaf varieties and street food, plus related user behaviors and needs. After data analysis, prototype packages were created: hard structure packaging made from fresh Noni leaves and bamboo strips and soft structure packaging made from dried leaves from the Purple Orchid tree and Banana tree derived cords. These multipurpose containers address the design criteria: supporting the food's weight, carrying both dry finger food and moist food and being held with one hand. Evaluation of the tools producing the packaging suggested development gaps related to simplicity were recognized.

Keywords: *Package Design, Single-Use Packaging, Leaf Packaging, Street Food, Plastic Waste, Pollution, Design Thinking Framework, Thailand*

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Introduction

Most countries around the world have faced a tremendous plastic waste crisis as the demand for plastic containers surges. Thus, world attention for a substitutes using other materials has been increasing. Thailand (Chanthamas and Israngkura, 2021; Faulder, 2021) and other Asian countries (Faulder, 2021) have been ranked as the world's biggest dumpers of plastic waste into the sea. Since plastic possesses a long lifetime but short service life, it is being dumped in greater proportions than it was in the past. At 2,331 million tons the single-use plastic packaging, hot and cold food bags, plastic straws and T-shirt bags, are the greatest proportions of discarded materials. The plastic waste after consumption was approximately 1.93 million tons. However, that plastic waste has been reused around 0.39 million tons (20.21%). The rest has remained as waste leading to environmental troubles of around 1.51 million tons (78.24%). Some of the waste gases have leaked into the environment at 0.03 million tons (1.55%) (Ministry of Natural Resources and Environment, Pollution Control Department, 2018:1-3). Plastic waste has contaminated habitation and food sources thus causing the extinction of both marine and land species and human health problems. (International Union for Conservation of Nature (IUCN), 2021)

This severe problem has raised public awareness, so the Thai government has issued a decree ordering all offices to develop a concrete plan to solve this problem. In 2018, the Pollution Control Department, Ministry of Natural Resource and Environment generated a national roadmap to tackle plastic waste between 2018 and 2030. The use of three plastic types: plastic bottle cap seal, oxo-mixed plastic, and microbead plastic was terminated in 2019. Additionally, the use of four plastic types: T-shirt plastic bags with less than 36-micron thickness, foam food containers, thin plastic glasses, and plastic straws will be revoked in 2022. The first goal of this plan is to reduce and stop using targeted plastic by replacing it with environmentally friendly material.

Recently, the plastic waste crisis is a result of packaging waste, so the Pollution Control Department developed packaging eco-design strategies to reduce unwanted waste. This eco-design package must be safe to dispose of and must not lead to waste problems and pollution. The disposal processes utilize three methods: biodegradation, landfilling, and incineration. Nonetheless, the inappropriate landfill can cause an environmental problem because of the lack of humidity and oxygen. The incineration can cause air pollution in a large area. Thus, biodegradation can be the best solution as it can turn the waste into a bio-fertilizer. A combination of organic substances is, therefore, recommended. The Ministry of Natural Resources and Environment, Pollution Control Department (2017) has recommended using degradable or natural-made packaging for the food vendors as their waste can be beneficial to nature.

Currently, a countless number of natural containers has been made through 1) the manual process such as Banana Stalk and leaf containers by C-sense Co. (Urban Creature, 2021), and 2) semi-automation techniques, the combination of machinery and manual processes such as Betel Palm trays by Veerasa Co. (Phinyovanich, 2021), Bastard Teak leaf dishes researched by Naresuan University (Chongchitwatthanakun, 2021), Water Hyacinth containers invented by Phachi Department of

Non-Formal Education (MGR Online, 2021), and leaf dishes by Leaf Republic Co. (Embassy of the Federal Republic of Germany, 2021).). Craft containers can be positioned in high-class markets, whereas machine-related procurement can be costly and limited to those who have funding or access to government support. Therefore, the cost per item of the containers referenced above is too expensive for single use. To fill this gap, the packaging in this research will be manually produced by a simple tool, which producers can make by themselves.

Hence, this research aims to 1) analyze design criteria for developing plant-based single-use packaging in response to government policy in plastic waste management, 2) create the packaging, and 3) evaluate tools for producing the packaging. This is to raise awareness in environmental preservation for those involved in research, both the participants and research users.

In this research, the term ‘packaging’ involves materials studied in the roles of containing, carrying, and communicating. Nonetheless, Kongcharoenkiat and Kongcharoenkiat (1998) have separated food packaging from food containers because their functions are different. The food container does not need to extend the food shelf life, to have a closed lid, and to present complete informed labels as inscribed in the law like the food packaging functions.

Methodology

Design Thinking has been applied as a conceptual framework of this research as can be seen in figure 1. Design thinking is the process to creatively achieve a solution through a human-centered approach consisting of three components: human desirability, business viability, and technological feasibility. Curedale (2016) has generated the design thinking processes into four elements; problem identification, understanding consumer’s needs, creativity, and creating a model for further development. Meanwhile, IDEO U (2019) has explained three main design thinking steps: empathy, ideation through brainstorming, and experimentation.

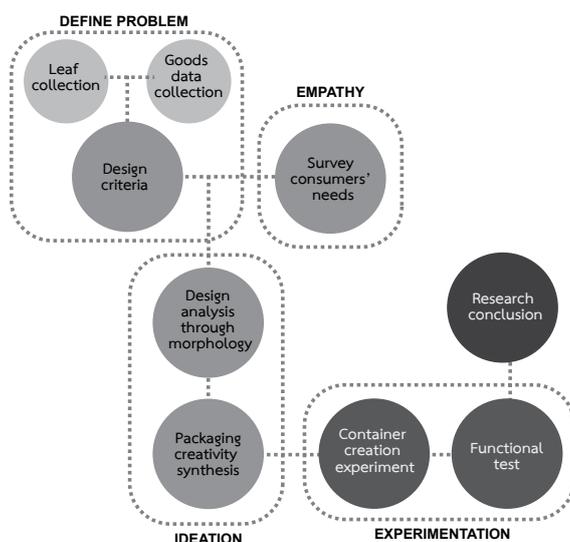


Figure 1. Research Design Thinking Procedure (Adapted from Hasso Plattner Institute of Design at Stanford University (2019)).

This research adopted pragmatic approaches where both qualitative and quantitative data were utilized to meet the research aims (Creswell, 2014). The numerical data of leave size, purchase frequency of popular street food items, and the dimensions of plastic containers available in the market were collected and analyzed to define problems (figure 1). The verbal data derived from observations and interviews with vendors and consumers were analyzed to identify their needs. The numerical and verbal data was used to clarify design criteria.

There are four components to be analyzed: leaves, street food menus, container types, and users (figure 2). The data obtained will be analyzed to list of the design criteria (figure 3).

Methodology		Analysis Results					
Leaves	<p>Literature review: Research to gain information of leaves, whose sizes are larger than 10 cm. x 10 cm., was taken from the Encyclopedia of Plants in Thailand (concise ver. 2020)</p> <p>Expert interview: A botanist, who has ten years of experience, was interviewed in regard to alternative, novel designs for food containers and her knowledge of unsuitable leaves</p>	Factors to be considered		Result			
		Economic Factor	Easy to find, to grow, and propagate	Edible large-size leaves which are easy to find.			
Physical Factor	Large size, tough leave, easy to form						
Biological Factor	Toxic-Free						
Street Food Menus	<p>Brainstorming & internet research: The initial list of popular street foods was derived from 1) individual brainstorming of 39 university students and 2) internet research. The students were from different universities and program levels, undergraduate and postgraduate, to ensure a variety of opinions. All results were tabulated, classified, and prioritized by the frequency of purchase and the foods' attributes. The attributes were used to identify suitable containers. The street foods represent samples found in targeted street markets</p>	Food features	Sub-features	Menus	Add-on Container		
Dry		crisp	Fried insect				
	Roti						
	Crêpe						
	non-crisp	Deep-fried rice flour with pandan flavor					
		Fried fish patty		side dish			
		Waffle					
		Soy sauce stirred fried noodles					
		Takoyaki					
		E-Sam Sausages		side dish			
	Moist	mixed food	Thai spicy fermented pork salad				
Green mango with Sweet fish sauce			watery dip				
non-mixed food		Chopped fruit		dried dip			
Watery food	with solid food	Boiled Chinese square pasta					
	without solid food	Coconut smoothie					
Remarks: Owing to the limitation of leaf physical features, liquids are omitted.							
Containers	<p>Internet research & field study: Collect the data of standard shapes and sizes of containers for popular menus from the internet and from street markets to form and classify the container types for the design.</p>	Types of Containers		Width (cm)	Length (cm)	Dia. (cm)	Height (cm)
		Flat	Small	11.5	17		2.5
			Large	16	17		2.5
		Shallow	Small			11.5	4.5
			Large			14.5	4.5
		Deep-dish	Small			11.5	7.5
			Large			14.5	7.5
		Add-on	Small			6	3
			Large			7.5	5.5

Figure 2. Methodology and analysis to deliver the design criteria. Continued on the next page.

	Methodology	Analysis Results	
End Users	Observations & interviews: Information concerning the functional use of street food containers was gathered from field observations. The users' need data was obtained from interviews with the 15 vendors and 15 consumers: five vendors and five consumers from each market. The information was gathered from three different styles of street markets: Laan Pho Market for the state authority officers, Rod Fai Ratchada Market for the new generation and Bang Bor Market for the general public. The data generated an insight into their packaging needs which could not be acquired from quantitative tools such as questionnaires. Denscombe (2017) suggested that the in-depth individual data reflect the general.	Opinions from the Users	
		Desired packaging	- Must be strong and can support stacked up weight. - Able to contain food for one hour without deformation. - Heat resistant material. - Cold and moist resistant material. - Container with cover to protect from dust while traveling. - Able to handle without a plastic bag. - Able to hold with one hand - Able to accommodate utensils - Able to accommodate, holding with one hand, add-ons of side dish/ sauce
		Problems from packaging usage	- Packaging toughness - Non-porous packaging is unable to maintain the food's crispness. - Thin paper package cannot protect the hand from heat. - Food can be contaminated by dust. - It is difficult to open the package as some vendors tie the rubber band tightly.
		Concepts for Bio-Containers	- The containers must be differently formed. - One design must be suitable for most menus. - The cost must be as low as the paper or plastic containers.
		The necessity for the logo	A logo can enhance the image, imprinting on consumers' minds, but having a logo on the containers can raise the cost of the package.

Figure 2 Cont. Methodology and analysis to deliver the design criteria.

Observation and Interview Procedure

The vendors and consumers were contacted in advance to ascertain if they were willing to participate in the research. Each was informed of the aim of the data collection and related ethical issues. The vendor observations included the space needed and methods used in preparing and handling food containers. The consumer observations centered on their behaviors related to carrying and opening food containers, and their methods of eating food from the containers. The interviews involved the vendors' and consumers' desired packaging. The vendors and consumers were also asked about the necessity for including a logo on the packaging.

Design Criteria		
To contain	<input type="checkbox"/>	Able to maintain the form
	<input type="checkbox"/>	Able to support the food weight
	<input type="checkbox"/>	Able to hold the soggy food
	<input type="checkbox"/>	Able to put the variety of food in one container; multipurpose
To protect	<input type="checkbox"/>	Accompany with cover to protect the dust
Convenience	<input type="checkbox"/>	Able to form within one minute
	<input type="checkbox"/>	Able to stack
	<input type="checkbox"/>	Able to hold with one hand
	<input type="checkbox"/>	Accommodate add-on utensils
	<input type="checkbox"/>	Accommodate add-on small bowl for sauce
Identity	<input type="checkbox"/>	Display necessary information

Figure 3. Design Criteria.

Creative Process

Part 1: Ideation

Through the brainstorming process, Morphological Analysis was applied to reveal new concepts by separating the components of attributes or functions of the product (Figure 4) (Zwicky, 1969). After selecting the designated components, a new form of relationship was created to inspire different concepts. This research focused on molding the leaf into a container and the stability of the leaf container (figure 5). Using Purple Orchid tree leaves in this research the findings lend themselves to two patterns: molding and stabilizing the container by leaving until it is dried; and molding the fresh Noni leaf with some techniques and equipment.

Functions	Procedures
To form	cut / mortise / thread / pile up / splice / fold / hold all the leaf / roll / pleat / fold with different axis/ overlap/ wrap / spiral roll / make a hold with a leaf stalk
To stabilize	splice the leaf edge / mortise and polish/ tie / clasp / fasten / tack / adhere with flour glue / leave until it's strengthened / put a logo sticker on to hold the package together/ perforate and overlap

Figure 4. Brainstorm for package formation and stability.



Figure 5. Brainstorm the ideas based on morphological analysis.

Part 2: Design

According to the design thinking framework a container design has been obtained. There are two designs to produce the container: the use of fresh leaves with hard frame structures and the use of dried leaves with soft frame structures. The processes can be listed as follows:

1. Design and select the handle material according to the criteria: biodegradability, low cost, and availability in the market
2. Set the street food and develop packaging according to its dimension
3. Check the lists whether it meets the design criteria or not
4. Arrange the load test by wooden dice
5. Try out the container by putting the street food inside.

Fresh Noni leaves (figure 6) and Dried Purple Orchid tree leaves (figure 7) have been used as the prototype because their size is large enough to carry the food and the leaves are free from toxins.

Containers created from fresh leaves and hard frame structures <i>(Samples: Noni leaves and bamboo stripes)</i>			
Container Structures			
	Fresh leaves		Bamboo Stripes
Container Design			
	A small flat container	A large flat container	A small shallow container
			
	A large shallow container	A large shallow container with a small add-on	A large shallow container with a large add-on

Figure 6. Containers created from fresh leaves and hard structures. Continued on the next page.

			
	A small deep-dish container	A large deep-dish container	A large deep-dish container with a small add-on

Figure 6 Cont. Containers created from fresh leaves and hard structures.

Containers created from dried leaves and soft frame structures (Sample: Purple orchid tree leaves and dried banana cords)			
Container Structures			
	Heat pressing the leaves into a mold	Dried banana cords	
Container Design			
	A small flat container	A large flat container	A small shallow container
			
	A large shallow container	A large shallow container with a small add-on	A large shallow container with a large add-on

Figure 7. Containers created from dried leaves and soft structure. Continued on the next page.

			
	A small deep-dish container	A large deep-dish container	A large deep-dish container with a small add-on

Figure 7. Containers created from dried leaves and soft structure.

Part 3: Tools

Tools have been developed based on business feasibility and the technical possibility to reduce the time of molding and stabilizing the container forms and sizes according to standards. This must not be varied according to the sizes of the leaves and the skills of the producers. There are three criteria of creating tools: easy to produce with simple technology, easy to find the materials, and low cost. Hence, the outcomes have been generated as follows: the models to control the size, microwavable plastic containers to mold the dried leaves, and nailed boards to model banana cords and bamboo stripes (figure 8).

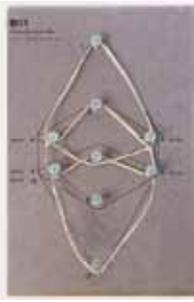
	Tools for producing the packaging	Tools for producing the handle
A container made from Noni leaves and bamboo strips		
	A model to frame the sizes of the fresh leaf packaging	A nailed board for modeling bamboo strips
A container made from Purple Orchid tree leaves and a banana cord		
	A microwavable model (800 watts: 1.5 minutes). This will take a longer time if left in the sun depending on leaf humidity and weather.	A nailed board for modeling a banana cord

Figure 8. Tools for producing the packaging.

Part 4: Identity

Showing the vendor’s identity on the packaging is one of the marketing strategies as customers will recognize it and will lead to repurchasing opportunities in the future. The tools to show the identity must be easily obtained in the market and the message or logo must be toxic-free. Research indicates that the most important information inscribed on the packaging is the name and telephone number of the vendor followed by social media contact. It is found that there are three methods of showing vendor’s signs or logos on the container: cold stamp, hot stamp, and pigment stamp (figure 9). The use of stamping tools depends on the physical features of the leaf and the position of pressing the logo.

The pigment stamp on the bamboo strips is suitable for fresh leaf packaging and the hot stamp is suitable for dried leaf packaging.



Figure 9. Logo stamping on fresh and dried leaf containers.

Evaluation of the Package Production Tools

The tools created for producing packaging were evaluated by 6 producers, 3 participants per packaging design. The volunteers aged 15 - 60 years old of both genders.

(Figure 8), The evaluated materials and packaging were made from Noni leaves and bamboo strips, and from Purple Orchid tree leaves and a banana cord. Due to the public social distancing policy during the COVID-19 pandemic, the participant number was minimized for health reasons. The participants were family or friends of the research assistants to diminish the risk of the virus infection. The assistants introduced the data collection objectives and the ethical issues. The participants were allowed to watch the video clip of using the tools and materials as many times as needed before producing the packaging.

The observations concentrated on 1) the preparation of the production space and 2) the steps involved in producing the packaging.

The interviews concerned 1) the difficulty or ease of producing the packaging with the tools, 2) suggestions on streamlining production and 3) the cost per packaging unit and the time for completing each unit.

Topics	A container made from Noni leaves and bamboo stripes	A container made from Purple Orchid tree leaves and banana cords
Overall production	<ul style="list-style-type: none"> It was difficult for novices, but it will be easier for a trained person. Allow producers to apply their own strategies. 	<ul style="list-style-type: none"> Leave containers were easy, but making the banana cord handles were difficult. Confusion ensued concerning the method and tying positions. One participant required an extra 20 minutes to understand the construction procedures. Older participants had more patience in learning the production techniques than the younger participants.
Tools	<ul style="list-style-type: none"> The bamboo strips can be simply measured by a tape or a ruler instead of the nail board. A tool needs to be developed for tying the banana cords. Decrease the size of the tool to save production space. 	<ul style="list-style-type: none"> The nailed board for producing the banana cord handles was difficult to understand. The numbers on the board did not clearly indicate; where to tie the rope, which cord asw on the top or underneath, or the up or down direction required while tying the cords.
Suggestion	<ul style="list-style-type: none"> Show the video clip at a slower speed. Add a voice explanation to the clip. Add more details concerning production steps. Specify using dry or fresh leaves for production. Reduce the production steps by providing finished bamboo structures. Modify the packaging handles, so that the packaging is stackable. 	<ul style="list-style-type: none"> The production was practical for the older participants, but it was time-consuming for the younger ones. Natural materials were cost-saving.
Completion time	<ul style="list-style-type: none"> Producing packaging while selling food should not be longer than 1 minute. Three minutes are acceptable for pre-production. 	Not more than 5-10 minutes per packaging unit.
Cost	<ul style="list-style-type: none"> Materials costs should not be more expensive than polystyrene containers. It could be 3-5 times more expensive than single-use plastic packages for green consumers. 	Approximately 5-10 baht per packaging unit.

Figure 10. Evaluation of the packaging production tools.

Discussion

The discussion below relates to the aims of this research

Design Criteria

Plant-based containers are already utilized in business and education. Betel Palm (Phinyovanich, 2021), Bastard Teak leaf (Chongchitwatthanakun, 2021), Water Hyacinth (MGR Online, 2021), and Banana Stalk and Leaf (Urban Creature, 2021) are researched examples of eco-friendly materials. These materials have strong fibers providing durability for multiple uses. In contrast, the purpose of plant-based packaging in this research focused on single-use containers for street food. The fibers of Noni leaves and Purple Orchid tree leaves have less strength than the above plant-based materials, which also allow them to decompose in a short time. This generates alternative new sources of leaves for street food containers.

Creation

This research found that the two types of packaging, fresh leaves with a hard frame structure and dried leaves with a soft frame structure, can serve three functional uses. First, the fresh and dried leaf containers can serve as primary packaging that contains food, whereas the hard and soft structures can serve as secondary packaging that carries food. The packing that holds the containers can also be substituted for plastic used to enclose T-shirts, thus resulting in fewer T-shirt plastic bags. This uniqueness is not found in other plant-based containers. Second, the tools have been created to combine industrial and manual functions, resulting in an affordable tool at a low cost. Finally, the two types of packaging with lids have met the consumers' need as they can protect the food from contamination. Additionally, it is found that dried leaves can be formed under heat and is comparable to other main containers available in the market.

Evaluation

This research aimed to fill the gap between the packaging made by a semi-machine process (Phinyovanich, 2021, Chongchitwatthanakun, 2021, MGR Online, 2021, Embassy of the Federal Republic of Germany, 2021) and packaging made by hand (Urban Creature, 2021). The research found means to reduce the cost of machinery procurement or manual molding time due to the leaves being shaped by simple molds available in markets. However, the research participants commented that 1) the production for Noni leaves packaging required the tools that tended to be handcrafted and 2) training was needed to acquire the skills to use them. Another concern was the lids from Purple Orchid tree; leaves needed to comply with the guidelines of appropriate leaf sizes and how to properly install the lids on the packaging. Finally, the instructions on the nailed board for constructing the banana cord needed to be more informative in guiding position and direction.

Conclusion

Recently, environmental protection has become a global megatrend, so natural containers have been continuously employed. Nonetheless, it is expected that those containers must be as durable as the plastic ones in order to be used more than once. Therefore, this research has fulfilled the missing gap of the need for

natural containers made from organic matter, leaves whose physical features are suitable for short-term use or single-use in the hope that they can be substituted for plastic containers, which is the majority proportion of packaging waste.

This research has been conducted during the COVID-19 pandemic. The number of participants involved in the evaluation stage was small to secure the health of both the research assistants and participants. This factor may weaken the reliability of the evaluation results, but helpfully it reflects that simplicity is the key direction for further development.

Suggestions

There may be copious, toxic-free large leaves available that are suitable for food packaging. A large number of natural alternatives that can be utilized in the packaging process according to the research result. Environmental economics studies related to the life cycle and location of plants should be conducted to manage the availability of the leaves to the market without resulting in ecosystem impact. This research targets individuals and small enterprises who establish themselves as packaging producers and makes contributions to affordable tools and learnable production methods. Nonetheless, the disadvantage of leaf packaging is the natural leaf odor which can distract from the palatable smell of the food. This is especially noticeable of the dried leaf which possesses more unwanted smell than the fresh ones. Therefore, it is recommended that odor elimination research should be conducted for further study.

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