A CONCEPTUAL DESIGN APPROACH ON THERMAL FOOD CONTAINER

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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ABSTRACT

Food container is one of the common products with the function as food temporary storage for travelling, walking, and etc. Usage of recycle food container is encouraged due to less impact on the environment. Even though there are plenty of food containers available in the market, there are limited designs of food container with reheat function. Hence, the purpose of this project is to develop and design a thermal food container with reheat function by using available green materials. Along this project, case study on current trend of thermal food containers is carried on. In contrast with that, comparison between current trends of thermal food container is also conducted. Overall, three design concept of thermal food container are proposed with thermal analysis using CFD software. In the end., the best design concept is selected and prototype is developed.

ABSTRAK

Bekas makanan adalah satu produk yang berfungsi untuk menyimpan makanan untuk sementara semasa perjalanan atau di luar rumah. Penggunaan bekas makanan berkitar semula digalakkan kerana tindakan ini mengurangkan kesan seperti pencemaran terhadap alam sekitar. Walaupun pelbagai jenis bekas makanan boleh didapati di pasaran, bekas makanan yang berfungsi dengan pemanasan semula adalah terhad. Oleh itu, tujuan projek ini adalah untuk membangunkan dan mereka bentuk bekas makanan haba dengan pemanasan semula yang dihasilkan menggunakan bahan-bahan hijau yang ada. Bersama projek ini, kajian kes terhadap ikutan semasa bagi bekas makanan terma dijalankan. Selepas itu, perbandingan antara bekas makanan haba trend semasa juga dijalankan. Secara keseluruhan, tiga konsep reka bentuk bekas makanan terma dicadangkan dengan analisis terma yang mengguna perisian CFD. Seterusnya, konsep reka bentuk yang terbaik dipilih dan prototaip dibangunkan.

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LIST OF SYMBOL

$\dot{Q}_{cond}$	=	Rate of heat conduction
k	=	Thermal conductivity
A	=	Area
T	=	Temperature
x	=	Thickness
h	=	Heat transfer coefficient
A_s	=	Surface of convection
T_∞	=	Temperature of fluid sufficiently far from the surface
T_s	=	Surface temperature
℃	=	degree celcious

LIST OF ABBREVIATION

CFD	Computational fluid dynamics
PET or PETE	Polyethylene terephthalate
PEN	Polyethylene naphthalate
PVC	Polyvinyl chloride
PVdC	Polyvinylidene chloride
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybuterate
TPS	Starch-based thermoplastics
PLA	Polylactide
PHV	Polyhydroxyvalerate
PHBV	Polyhydroxyvalerate
PBV	Polyhydroxybutyrate-valerate
Sn	Tin
Zn	Zinc
EPA	Environment Protection Agency
FDA	First Division Association
PVC	Polyvinyl chloride
PVdC	Polyvinylidene chloride
PHB/V	Poly(3-hydroxybutyrate-hydroxyvalerate) copolymers
PEA	Phenylethylamine
PBSA	Poly(butylene succinate adipate
HOQ	House of Quality
PCL	Polycaprolactone
PET	Polyethylene terephthalate

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF THERMAL FOOD CONTAINER

Thermal food container is an insulating storage for food that able to keep food fresh and hot. Insulated food containers are very common in among people of all ages and commonly used to pack lunch from home. Usually, from preparation of food to actual consumption time taken a period of five to six hours (Tiffany and Chu, 2013). Risks associate when the food is consumed with improper temperature. Besides, food which undergoes time and temperature abuse will enhance the survival and growth of pathogens, thus there is possibility for consumer contract foodborne illness.

In contrast with that, the major cause of food poisoning has been identified as improper food handling. When food is not prepared or stored safely, it will be contaminated which allows survival and growth of pathogen (HealthLinkBC, 2011). Moreover, inadequate reheating for hot holding and improper hot holding temperature which in between 4˚C to 60˚C easy to cause foodborne illness in among children (British Columbia FOODSAFE Secretariat, 2006). On the other hand, plastic containers with microwavable or microwave-safe label only meant should not melt, crack or fall apart when used in microwave. Somehow, the label does not guarantee that containers do not leach chemicals into food when heated. Besides, plastics are made of non-renewable resources that require new fossil reserves to be extracted continuously. Hence, non-eco-friendly materials do impact on environment and cause pollution.

In context with that, a conceptual design of reheat-able thermal food container was invented in this project to extend the freshness of the food consumed and to keep the food warm. Besides, this project aims to improve the lifestyle of the society.

By end of this project, a conceptual design on thermal food container will have the ability to extend the freshness of food and influence the society using food container instead of food packaging.

1.2 OBJECTIVES

1. To design and develop a thermal food container with reheat function and temperature detector.
2. To propose the usage of green materials in developing the thermal food container.

1.3 PROJECT SCOPE

1. Conducting analysis based on temperature and heat losses of the design.
2. Developing the innovative model of the thermal food container with shape that is easy to clean and has good resistance.
3. Conduct a case study on current trend of thermal food container design.
4. Design comparison with current trend of thermal food container.
5. Design modification on current trend thermal food container using green materials.
6. Analysis on the design of modified thermal food container.
7. Prototype development of modified thermal food container.

1.4 PROBLEM STATEMENT

When food is not prepared or stored safely, it can become contaminated which enhances survival and growth of pathogens (HealthLinkBC, 2011). Food safety meant the holding temperature should in between 4˚C to 60˚C before consume by user. Although there are existing thermal food container that able to hold temperature of food, but food container without reheat function is not efficient enough to achieve food safety as the duration for thermal food container holding the temperature is limited.

In context with existing food containers, most of them were made from plastic, which is a non-renewable renewable resource. Plastic requires new fossil reserves to be extracted continuously. Besides, plastic is also a non-biodegradable material. As the material is non-biodegradable, the wastes will cause pollution and cause impact on environment.

Furthermore, when reheat function apply on food container the probability of food been overheated should be considered to prevent the damage on food nutrition or food becomes too dry to be consumed. Meanwhile, the temperature of food container is not detectable.

CHAPTER 2

LITERATURE REVIEW

This chapter covers the background study for food container. Besides that, the chapter also cover several types of materials, theory of heat transfer system, basic electrical and electronic principles, CFD simulation of heat.

2.1 HISTORY OF FOOD CONTAINER

Early of century, food was consumed at where it was found. Families and villages were self-sufficient, they making and catching for food (Hook and Heimlich, 2012). As human life style is changing, containers become a necessary tool kit. Human use nature provided gourds, shells (Figure 2.1), and leaves to use. Later, containers were transformed from natural materials, such as hollowed logs (Figure 2.2) and woven grasses (Figure 2.3).

Figure 2.1: Shells used for food storage (Nature's Own Design's, 2009)

Figure 2.2: Hollowed logs used for food storage (Hollowed Out Birch Log, 2013)

Figure 2.3: Woven grasses used for food storage (African Craft Market, 2010)

In Egyptian and Roman times, containers were made by clay and other materials. Later, materials such as glass, metal and paper were introduced (Muhammed, 2007).

By Victorian times, butter and cheese were kept in baskets, vinegar in barrels, tea in chests and grain in sacks (Muhammed, 2007).

The Elizabethan way of keeping drinks cool was to keep the jugs in a tub of water, this theory of this idea is the evaporation helps to keep the liquids cool (Muhammed, 2007).

Figure 2.4: Elizabethan kept the jugs in a tub of water (Robert and Mellin, 2010)

Hence, this idea comes with the current product in Figure 2.5. The food container keeps the temperature by pouring hot or cold water in the middle layer.

Figure 2.5: Thermal food container with hollow tube at centre (Tan, 2012)

In 1643, the Italian support created mercury vacuum theory put forward the famous pressure table. This theory is very important to be applied in thermos bottle, however, in the later 2.5 centuries; the real thermos bottle can't be invented yet (Wang, 2013). More than a century ago, Sir Dewar, a famous physicist and chemist invented the thermal flasks. Initially the thermal flask known as Dewar Flask, later the production started commercially in 1904 by German Thermos Flask Manufacturer (Wang, 2013). The vacuum flask structured by the liner, shell and additional components. While the liner is composed of two glass bottles together, shell has certain strength in order to protect and increase the decorative effect. These vacuum flasks are normally made from glass or stainless steel. The vacuum flask called glass refills or glass liner if made of glass, in opposite, called double wall stainless steel if made of stainless steel (Wang, 2013).

In 1795, a prize was offered by Napoleon to anyone in France who could come out with an idea which able to keep food safe for his soldiers. Nicholas Appert, a chef from Paris, took up the challenge and invented a method of preserving food by heating it in sealed container (The History of Packaging, 2010). Meanwhile, scientists in England discovered that steel covered with a very fine layer of tin, made an ideal packaging material and able kept food fresh.

2.2 CASE STUDY

Case study has been continued from reheat lunch box by Tan, 2009. The reheat lunch box is using aluminium and plastic to fabricate the product. Besides, the build in thermal system using thermoelectric cooler Peltier to produce heat and cold at the same time.

2.2.1 Food safety

There are many children who often bring packed lunches from home, and actually the foods provided by parents sometimes are potentially hazardous. Thus, parents must be handled safety before the lunches being served to their children (Miller et al., 2013).

Potentially hazardous foods mean foods that are low acid, moist, and contain protein. One of the methods for keeping potentially hazardous foods like meat, dairy, and some cut fruits and vegetables is temperature control, in refrigeration. Besides, foods in refrigerator should kept below 5°C to prevent reproducing of bacteria and other microorganisms. Lunch boxes brought from home are normally expose in room temperature, while the temperature of food able to increase though out the day and possibly reaching temperatures in excess 17°C (Tiffany et al., 2013). Sometimes, lunch boxes are keep with ice packing to keep food cold, but this method might not effective enough to maintain food stay below temperature of 5°C. A study conducted in six child-care centers in Texas found that only 22 of 1631 (1.35%) potentially hazardous food items tested were in the acceptable temperature range, including 2.27% of lunches with one ice pack, 8.2% of lunches with multiple ice packs, and 0.9% of lunches kept in the refrigerator (Miller et al., 2013). These results may cause by of the lunch sacks, the amount of time at room temperature before refrigeration, or the internal temperature of the refrigerator.

Furthermore, some of the lunch boxes prepared from home required to reheat before consume, and the reheat step must do it safely. This is because food that stored at unsafe temperature after reheating provided ideal pH environment for the growth of bacteria because it contains nutrients and water. Bacteria able grow multiply rapidly in the food with a temperature range between 5°C and 57°C, which is called the "temperature danger zone." If the reheated food is stored in the danger zone for more than 4 hours, the number of pathogenic bacteria may reach the infectious dose or produce toxins which able to cause foodborne illness once it is consumed (Miller et al., 2013). This is important for consumers to note that lunch boxes are safer is consumes after short period of reheat.

2.2.2 Heat sterilization

One of the most common preservation processes for food is heat sterilization. Heat sterilization makes storage life of food longer and safer for consumption, inactivating enzymes and destroying pathogenic microorganisms. During heat sterilization process, heat transfer can occur by conduction or by either natural or forced convection according to food structure and characteristics of the heating system. Conductive heating has been the most studied alternative whereas convective heating has been paid little attention. This is due to the inherent complications to solve simultaneously the coupled heat, mass and momentum balances in liquid and semi-liquid materials (Lespinard and Mascheroni, 2010).

In liquid foods, natural convection which is caused by density gradient within the liquid was due to a temperature gradient. For motionless cases, when natural convection occurs, the slow heating zone moves toward the bottom of the container. The slow heating zone is defined as the region within a container of product which receives the lowest sterilization treatment during thermal processes (Zechman et al., 1989). From heat sterilization, thus the lunch is applied with idea reheat function.

2.2.3 Impact from food packaging

Food is the requirement of human with minimum three times per day. Consequently, the waste from food packaging is almost 33.3% from total packaging waste in volume (Hunt et al., 1990). Besides, 50% by weight from total packaging sales is for food packaging usage.

The main purposes of food packaging are aim to protect food products from outside influence or damage (Coles, 2003). Traceability, convenience, and tamper indication are secondary purpose and which increasing its importance today. In contrast with that, to satisfy industry requirements and consumer desires, the purposes of food packaging becomes more important in reduce the packaging cost.

In context with that, why not replace the position of food packaging with a lunch box? Since, food packaging is commonly thrown away. Besides, by using a reuse able lunch box able to contribute in food waste reduction.

2.3 IMPROPER FOOD HANDLING

Foodborne illness occurs when a person consumes food or beverage that has been contaminated with a particular type of bacteria, virus, mould or parasite (HealthLinkBC, 2011). Reheat foods by using microwave sometimes cause the food cook unevenly and resulting cold spots. While cold spots are where the harmful microorganisms survive in food when it is not sufficiently killed (Florida Department of Health, 2012). Furthermore, there is another problem cause when food is overheated. Overheated food will lose its nutrition and thus too hot or too dry to consume.

2.4 HEAT TRANSFER IN THERMODYNAMIC

Heat and mass transfer is a basic science that deals with the rate of heat transfer of thermal energy. The science of thermodynamics deals with the amount of heat transfer as a system undergoes a process from one equilibrium state to another, and makes no reference to how long the process will take. There are 3 basic mechanisms of heat transfer, which are conduction, convection, and radiation. Conduction is the transfer of energy from the more energetic particles of a substance to the adjacent, less energetic ones as a result of interactions between the particles. Convection is the mode of heat transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. Radiation is the energy emitted by matter in the form of electromagnetic waves (or photons) as a result of the changes in the electronic configurations of the atoms or molecules (Cengel et al., 2011).

Thermal food container is a close system as shown in Figure 2.6; there are only conduction and convection in heat transfer system.

Figure 2.6: La gourmet Lunch Box (lazada.com)

2.4.1 Conduction

The rate of heat conduction through a medium depends on the geometry of the medium, its thickness, and the material of the medium, as well as the temperature difference across the medium.

The law of heat conduction also known as **Fourier's law of heat conduction.** Fourier's Law state that the rate of het conduction through a planar layer is proportional to the temperature difference across the layer and the heat transfer area, but is inversely proportional to the thickness of the layer.

$$Rate\ of\ heat\ conducion \propto \frac{(Area)(Temperature\ difference)}{Thickness}$$

Or,

$$\dot{Q}_{cond} = kA\frac{T_1 - T_2}{\Delta x} \qquad (2.3\text{-}1)$$