# Highlight of food packaging development biology essay

Science, Biology

Food packaging is a necessity for every kind of food. Without food packaging the safety and quality of food would be compromised and pervasive as almost all the food is packaged in some way.[1][2] An ideal food packaging must be able to perform a number of different tasks: protecting the contents from contamination and spoilage, making transportation and storages of the product easy, providing a uniform measurement of contents, promoting the product and inform the consumer, and finally convenience, as consumers usually prefers a convenient packaging.[1][3]According to books by Gordon L. Robertson, he mentioned that an appropriate design packaging is essential to allow a package to protects what it sells as well as to sell what it protects.[1][2][3] Hence there are four primary function of packaging which must be interconnected, assessed and considered simultaneously in the packaging development process.[3]ContainmentThe ability of a packaging to contain the product is very obvious and tends to be overlooked by many. All products must be able to be contained in the packaging before any transportation. Without the containment function, contamination and the loss of product would be rather extensive. Hence, the containment function provides a huge contribution into protecting the environment from the uncountable products which are moved from different locations in all sorts of events. A faulty design packaging could lead to a major pollution to the environment. ProtectionThe primary function of a package is to protect the packaging`s content from the outside environmental effects such as gases, water, moisture, vapor, odors, micro-organisms, shocks, dust, vibrations and compressive forces. It is also to protect the environment from the product. For most of the food, the protection provided by the packaging is an essential part in the preservation process. For example, aseptically packaged milk and fruit juices in paperboard cartons can only remain aseptic for a period of time as long as the package provides protection. A vacuum-packaged meat will not achieve its desired shelf life as well if the package allows oxygen to enter. In general, once the integrity of the package is breached the product can no longer be preserved. Packaging protects or conserves much of the energy expanded during the production and processing phase of the product. For example, the energy required to produce the product would take its form in terms of the energy required to convert the raw materials to the product. Transportation takes its form of energy as transport fuel. Although the production of the packaging film requires a little more energy to produce the package, the spoilage of the product itself without the packaging has a larger consequence as compared to the usage of the packaging with a smaller increase in the total energy production.[3]ConveniencePackaging plays an important part in allowing products to be used conveniently, in this modern, industrialized society, lifestyles are undergoing tremendous changes. However, food/ food packaging is still a necessity in our daily lives. These changes have caused a demand for greater convenience in household products such as food that can be prepared beforehand and can be cooked or reheated in a very short time, and if possible, without removing them from the package; re-closeable openings on the drink bottles to allow consumption on the go and many more. In addition, apportionment function of packaging should also be considered in the design of the food packaging where in this context, the package function to reduce the output to a manageable desirable " consumer' size from industrial production. Another factor would be the relation of the primary package to the convenience of use by the consumers to allow easy holding, opening and pouring as appropriate as possible. Hence all these have cause the packaging to respond to those demands and changes.[3]CommunicationAs mentioned above, " a package must protect what it sells and sell what it protects" that is defined as the role of the package as a " silent salesman".[1][2] The distinctive branding and labeling allows the package to communicate its messages to the consumers enabling a self-service basis in the supermarkets to support the modern methods of consumer marketing. For example, consumers can make their purchase of products just by the numerous clues provided by the graphics and the distinctive shapes of the packaging which includes the ingredient and nutritional information, as well as the country of origin. The Universal Product Code (UPC) are also incorporated as a function on the packaging itself for a more accurate and rapid reading using a modern scanning equipment at the retail checkouts.[1][3]

## 2. 1. 2New Technologies in Food Packaging

As mentioned, traditional basic function of packaging aims to protect, communicate, convenient, and contain. These functions are not totally exclusive but an interconnected network within each other. Therefore, after all these years of experimenting and research, human have developed many different types of food packaging that is suited for different storage condition instead of adopting the traditional packaging using passive barriers to delay the negative effects in the environment.[4] Food packaging has been progressing into a new era. Some of these include technologies such as controlled atmosphere storage and modified atmosphere storage, intelligent/smart food packaging and also active packaging. These systems are incorporated into the packaging with the intention to increase the shelf-life of the products.

## 2. 1. 2. 1Modified Atmosphere Packaging

The controlled/modified atmosphere storage is a relatively old process according to ancient writing. Certain forms of modified atmosphere storage were used in China, Greece and other early civilizations. In some of those reports, some of the fruits were sealed in the package together with grass and fresh leaves. Over time, as the grass, fruits and the leaves the atmosphere inside the packaging was modified into an environment high in carbon dioxide and low in oxygen which retard the process of the fruit ripening inside the package. A similar study was done in the 1930s on the effects of carbon dioxide and storage temperature that would affect the inhibition of microbial growing on the meat surfaces. The results show an extension in product shelf life. Hence, in the late 1950s the first significant trails of retail size modified atmosphere packaging (MAP) took place with vacuum-packed meat, fish and coffee. In the 1970s and 1980s there are an increase in the number of researchers who are interested in the gas preservation techniques and commercial applications of MAP using nitrogen (N2), oxygen (O2) and carbon dioxide (CO2) have steadily increased since then. The purpose of using MAP is to extend the shelf life of food products and to prevent (at least retard) any undesirable changes in the wholesomeness, safety, sensory, characteristics, and nutritive value of foods by the following three principles:[5]Reduces undesirable physiological, chemical/biochemical and physical changes in foodsControls microbial growthPrevents product contamination like any other packaging techniques

## 2. 1. 2. 2Active Packaging and Intelligent/Smart Packaging

Figure 2-1: Model of packaging function [6]Active and smart/intelligent packaging is the main areas in which most of those innovative ideas from researches have been applied which satisfy the needs to widen and redefine the functions of food packaging. In active packaging, the protection function has a shift in the concept from passive to active. The primary basic primary packaging materials only function as an inert barrier for protection of the product against oxygen and moisture. These functions were considered to be `passive'. As the packaging technology developed, new packaging materials have been developed to provide `active' protection for the product. In which active packaging has been defined as a system that the product, the package and the environment interacts in a positive way to extend the shelf life or to achieve some characteristics that cannot be obtained otherwise. All the active packaging technologies would involve physical, chemical, or biological action for changing interactions between the packaging, the product, and the package headspace for a certain desired outcome. Hence, they can be divided into three categories mainly releasing system, absorber, and other system.[6]According to Figure 2-1, smart packaging was placed above the communication function in where, smart packaging is a provider of enhanced communication while active packaging is a provider of enhanced protection. Therefore, in the whole packaging system, smart packaging is responsible for sensing the environment and processing information to its consumer and manufacturer, it possess the ability to track the product, sense the environment inside or outside the package, and communicate with human. For example, a smart package would be able to monitor the quality/safety condition of a food product and give early warning to the consumer of food manufacture. Active packaging is the component responsible for taking action, i. e. release of an anti-microbial, in order to protect the food product.[6] An ideal food packaging would have all the various functions from smart, active and traditional packaging working together for an appropriate situation to provide a total packaging solution.

## 2. 2Active Packaging Technology

## 2. 2. 1Introduction

As the standards and quality of everyday living increases, people are now demanding for more minimally processed and ready-to-eat `fresh’ food products. This is due to the fact that recently there are more food-borne microbial outbreak in the world.[7] The demands includes the globalization of food trade as well as the distribution from centralized processing in which all of these factors creates a major challenges for the food-packaging industry with respect to the maintenance of the products safety and quality. As the standards of food packaging increases, the function of a traditional packaging system seems to have reached its limit with regards to further shelf life extension of the packaged food.[8] In order to surpass that limit and to improve the quality, safety and integrity of the packaged food. Newly innovated active and intelligent packaging concepts have been developed to meet those demands. As mentioned, traditional food packages are designed to delay the adverse effects of the environment on the food product from its passive barriers. The active packaging concept will allow packages to interact with food and the environment so as to provide an active role in food preservation.[8] According to a European, Actipack project, active packaging has been defined as the packaging which `changes the condition of the packed food to extend shelf life or to improve safety or sensory properties, while still maintaining the quality of packaged food’.

## 2. 2. 2Types of Active Packaging

Active packaging systems are specially designed to be a diverse, broad concept for specifically certain range of food product shown in Table 2-1. Active packaging consists of two main categories. Firstly active releasers/emitters i. e. packaging that release beneficial active compounds into the food/surrounding. This category usually consists of anti-microbial, anti-oxidative active packaging which includes aroma and carbon dioxide releasers. Secondly, active scavengers/absorbers i. e. packaging that absorb unfavourable components from the package headspace and/or the food itself. This category consists of oxygen, carbon dioxide, ethylene scavengers, and moisture and aroma absorbers.[6][8]Table 2-1 Potential Application of Active Packaging Technologies[8]

## Types of Active Packaging

## Food Products

Oxygen scavengersSmoked and Cured meats, fish, cheese, bakery products, fresh pasta, ground coffee, tea, chips, vegetables, milk powder, cakes, cookies, beer, wine and beveragesEthylene scavengersFresh produce, fresh-cut productsCarbon dioxide scavengersGround coffeeMoisture regulators/absorbersDry products, meat, poultry, fishAroma scavengers/absorbersCitrus juicesAntioxidative packagingCereals, milk powderCarbon dioxide releasersFish, Meat, butter, poultryMicrowave susceptorsReady-to-eat meals, French fries, popcornAntimicrobial packagingMeat, poultry, cooked ham, fish, cakes, bakery products, fruits, cheese

## 2. 2. 1. 1Oxygen-Scavenging Packaging

In the past, oxygen-sensitive foods and beverages were packaged in various ways to minimize their exposure of oxygen in the environment. The oxygen maybe present in the package at the time of sealing, there could be possibility that it could enter the pack by the permeation or leakage over the storage life. The presence of oxygen will allow reactions in the food package. The impact of oxygen on food quality, and shelf life is not only dependent on the quantity of oxygen available for chemical oxidation or support of growth of organisms but also the rate of the reactions of food which consumes the oxygen.[5]Oxygen-scavenging are classified as an active scavengers/absorbers packaging where O2 absorbers are used in the packaging i. e. powdered iron or ascorbic acid. Using these powdered irons, it would allow the possibility to reduce O2 concentration in the headspace to less than 0. 01%. This is much lower than the typical 0. 3-3. 0% residual O2 levels which are achievable by vacuum or gas flashing. The reaction using powdered iron scavenger is shown below. Fe ☾ Fe2+ + 2e½ O2 + H2O +2e ☾ 2OH-Fe2+ + ¼ O2+ ½ H2O ☾ Fe (OH)3Fe(OH)2 + ¾ O2 + 1 ½H20 ☾ Fe

$(OH)_3$For those well know $O_2$ scavengers, most would take the form of small sachets contacting various iron-based powders, together with various catalysts that scavenge $O_2$ within the food package and irreversibly convert it to a stable oxide. As shown in chemical equation above, water is required for $O_2$ absorbents to function, in some sachet. The water is added during manufacturing, while in others, moisture must be absorbed from the food before $O_2$ can be absorbed. Iron powder is separated from the food by keeping it in small sachets which are not meant to be eaten. They are highly permeable to $O_2$ and sometime water vapor. Usage of iron-based scavengers can be a disadvantage as they normally cannot pass the metal detectors that are often installed on packaging lines. Hence, non-metallic $O_2$ scavengers which includes organic reduction agents i. e. ascorbic acid, ascorbate salts or catechol and enzymic $O_2$ scavenger systems using glucose oxidase or ethanol oxidase, which can be added into sachets, adhesive labels or immobilized into package surfaces are substituted with the iron-based scavengers.[3] In addition, in order to prolong the product shelf life and enhance the overall performance of the absorbent, films are contained with PVdC or EVOH copolymer as it gives a good barrier layer. These films have an $O_2$ permeability of [< 0. 004 X $10^{-1}$[mL(STP)cm $cm^{-2}$ $s^{-1}$ (cm Hg)$^{-1}$] and the headspace $O_2$ reduced to around 100ppm in 1-2 days and remain at that level for the duration of the storage period, provided packaging integrity is maintained.[3][9]

## 2. 2. 1. 2Carbon Dioxide Generating/Absorbing System

There are mainly two types of carbon dioxide active packaging. These are sachets available that are based on either ascorbic acid and ferrous carbonate or ascorbic acid with sodium bicarbonate that absorb O2. Due to the reaction give back an equivalent volume of CO2. The emission of CO2 responding to O2 gas absorbed can be described by the following reaction: 4 FeCO3 + 6 H2O + O2 ☾ 4 Fe (OH)3 + 4 CO2In absence of this mechanism, the packaging would collapse due to the volume reduction or pressure decrease of the headspace atmospheric gas. In addition, the high CO2 concentration in the package can also contribute to retarding microbial growth.[3][6]CO2 gas absorbing sachets are rare, whereas absorbent sachets that contain Ca(OH)2 in addition to iron powder are more common, as a result it absorbs CO2 as well as O2. In applications such as packaging for roasted or ground coffee, this is a very useful function as the fresh roasted coffee itself releases considerable amount of CO2 and unless removed, it can cause the packaging to swell or burst due to the pressure built up.[3]

## 2. 2. 1. 3Ethanol Generating Systems

Ethanol (ethyl alcohol) has been used as an antimicrobial agent for many years. According to Gordon L. Robertson, previously this method was used to prevent mold spoilage of fruits. In Japan high-moist bakery used this method vastly to extend the shelf life up to 20 times as ethanol exhibits antimicrobial effects even at low concentration. The sachets contain ethanol and water, which are adsorbed onto SiO2 powder and filled into a paper- EVA copolymer sachet. A main disadvantage of using the ethanol vapors other than cost would be the formation of off-flavour and off-odors in the product. The absorption of ethanol from the headspace by the food can go up to 2% concentration in the food which results in regulatory problems. However, there would not be an issue if the food is required to be heated in an oven before consumption as the ethanol being volatile will evaporate off. Some sachet contains traces of vanilla or other flavours which are used to mask the odor of alcohol.[3]

## 2. 2. 1. 4Anti-microbial Packaging

According to Han, anti-microbial (AM) packaging is a system that can kill or inhibit the growth of micro-organisms and thus extend the shelf life of perishable products and enhance the safety of packaged products. Most of the AM packaging systems are based on direct contact between packaging material and the surface of the food. The AM agents are incorporated into or coated on the packaging layer. Some of these AM functional groups would be attached to the polymer backbone. This would include bioactive agents such as enzymes and other organic compounds which could be incorporated in the packaging material matrix maintaining their AM activity as themselves.[1][5][6]Tremendous research and development were carried out over the last decade for film testing with AM properties to improve food safety and shelf life. Among many applications such as oxygen-scavenging packaging and moisture-control packaging, AM packaging would be one of the most promising innovations of active packaging technologies. The creation of new AM packaging systems can be discovered by incorporating various AM and materials into conventional food packaging. Table 2-2 shows potential AM agents anti food grade-grade preservatives. These agents can be classified into three groups, chemical agents, natural agents and probiotics.[1][5]Table 2-2: Examples of potential antimicrobial agents for antimicrobial food packaging system[5]

## Classification

## Antimicrobial agents

Organic acidsAcetic acid, benzoic acid, latic acid, citric acid, malic acid, mixtures of organic acidsAcid saltsPotassium sorbate, sodium benzoateAcid anhydridesSorbic Anhydride, benzoic anhydridePara benzoic acidsPropyl paraben, methyl paraben, ethyl parabenAlcoholEthanolBacteriocinsNisin, pediocin subtilin, lacticinFatty acidsLauric acid, palmitoleic acidFatty acid estersGlycerol mono-laurateChleating agentsEDTA, citrate, lactoferrinEnzymesLysozyme, glucose oxidase, lactoperoxidaseMetalsSilver, copper, ZirconiumAntioxidantsBHA, BHT, TBHQ, iron saltsAntibioticNatamycinFungicidesBenomyl, Imazalil, sulfur dioxideSanitizing gasOzone, chlorine dioxide, carbon monoxide, carbon dioxideSanitizersCetyl pyridinium chloride, acidified NaCL, triclosanPolysaccharideChitosanPhenolicsCatechin, Cresol, HydroquinonePlant VolatilesLinalool, eugenol, thymol, allyl isothiocyanate, cinnamaldehydePlant/Spice extractsGrape seed extract, rosemary oil, basil oil, beta acidProbioticsLactic acid bacteria

## 2. 2. 1. 4. 1Chemical Anti-microbial Agent

In food preservation, the entire packaging ingredient should be food-grade additives as the chemical agents are mixed with food ingredients and incorporated into packaging additives/inserted into the headspace atmosphere where AM agents are in contact with and consumed with the food products. Due to such applications, the chemical AM agents should be controlled as a food ingredient regardless of the initial position of the chemical AM agents (in the food product, in the packaging material, or in the package headspace atmosphere). In the case of the non-food-grade chemicals, one way to introduce the chemicals into the food packaging system is through a chemical binding of the AM agents to packaging material polymers (Immobilization), the simplest form of fabricating AM plastic packaging is by extruding the polymer master batch together with the active substances which in this case the AM agents.[5][6] One application is the silver substituted zeolites called Zeomic®. To date, it is the only Food and Drug Administration (FDA) approved materials for direct food contact. Zeomic® is widely used for food applications especially in japan as a polymer additive. The sodium ions present in zeolites are substituted by silver ions, which have a high antimicrobial activity against a large range of bacteria and molds with a very low human toxicity. The substituted zeolites are incorporated into polymers such as low density polyethylene (LDPE), polypropylene. The microbial cell present in the food product will then take the Silver ions up which would disrupt the cells enzymatic activity.[3][7]The other common types of chemical AMs used by researchers are the types of organic acids which are due to their efficiency and cost effectiveness.

Previously, many organic acids which include fatty acids are naturally existing chemicals. Now, most of them are produced by chemical synthesis or chemically modified from the natural acids i. e. sorbic acid, sorbates and fungicides.

## 2. 2. 1. 4. 2Bioactive Anti-microbial Agent

Bioactive AM agents/Natural AM agents are a naturally occurring AM agent which includes herb extracts, spices, enzymes and bacteriocins. Food manufacture are now using more of these naturally occurring AMs to sterilize and/ or to extend the shelf life of food as the consumers are demanding usage of chemical preservatives-free food. The extracts from these herbs and spices contains multiple natural compounds and are known to have a wide AM spectrum against a wide range of micro-organisms.[5] Examples of natural extracts are linalool from sweet basil herb, amexol from rosemary (Rosemarinus officinalis L.), grapefruit seed extract and many more, see Table 2-2. One of the popular natural AM agents is sweet basil herb as mentioned above. This agent has been used widely in food products and as an ingredient in dental products. The immobilization of basil extract into LDPE films are effective AM activity against various microorganism such as staphylococcus aureus, listeria annocua, escherichia coli and saccharomyces cerevisiae. In general, natural antimicrobial agents can be coated on the packaging itself or even blending with polymer with the natural substance by extrusion technique to create an antimicrobial film.[10]

## 2. 3Controlled Release Mechanism (CRM)

## 2. 3. 1Introduction

Conventionally, foods are dipped into or premixed with active agent, i. e. antimicrobial agent and antioxidant, to preserve and extend the shelf life of the food. Over the time, natural processes such as consumption and deterioration of active agent kicks in and the concentration of active agents in the food falls.[11] As a consequence, long term protection of food could not be achieved. In addition to short effective life span, lack of selectivity to target the food surface, i. e. place where most microbial and oxidative spoilage intensively occurs, due to diffusion has also made the conventional method non-ideal for protecting foods effectively. Subsequently, controlled release technology came into the picture and thought to be helpful in solving the limitations mentioned earlier. Controlled release technology can be incorporated into the food packaging and allow continuous release of the active agent to the food at the critical concentration necessary for suppressing microbial activity and oxidative reactions.[12][13] Essentially, the continuous release of active agent would replenish active agent used up over the time in the system and prolonged the effective life span of the active agent. Moreover, the controlled release technology can be designed for targeted delivery which allows active agent to be released specifically from the packaging to the food surface only instead to the whole food. On top of resolving limitations faced, controlled release technology allow features such as incorporation of high dosage active agent, delayed release of active agent, incorporation of two or more active agents & release of different agents at different time and etc. to be designed into the packaging.

## 2. 3. 2CRM for Food Packaging

Primary goal of controlled release technology is to design a delivery matrix that allows release of active agent(s) in a pre-designed manner. As food packaging is of interest, the following sections would be discussed in the context of designing food packaging material as the delivery matrix.

## Diffusion induced mechanisms and dissolution/degradation induced mechanism are two most commonly employed CRMs. Other mechanisms such as hydrogel based CRM and polymer-active agent complex CRM were reported also. Every category would be discussed and elaborated with their possible applications in the following sections.

## 2. 3. 2. 1Diffusion Induced CRM

Diffusion induced CRM is a controlled release delivery matrix designated such that the active agents are released in a controlled manner via diffusion. Distinct feature of this mechanism is the high stability in dimension – volume and cross-section area of the delivery matrix do not change throughout its servicing life. Figure -2: Two possible configurations designed based on diffusion induced CRM [14]Diffusion induced CRM is further categorised into monolithic CRM and reservoir approach CRM, see Figure 2-2. Presence of diffusion rate controlling membrane in reservoir approach CRM differentiates itself from monolithic CRM.

## 2. 3. 2. 1. 1Monolithic CRM

In this mechanism, the delivery matrix is fabricated by homogeneously dispersing the active agent throughout the matrix material. Mechanically mixing the matrix material along with the active agent in a twin screw compounder or dispersing active agents inside a solid scaffold structure, i. e. hydrogel, are typical examples of fabricating monolithic delivery matrix. Similar design of CRM has also been reported in numbers of papers.[12][15]Active agent releasing behaviour of this system is largely depending on the solubility and permeability of the active agent in the matrix material used. Therefore, depending on the type of the active agent and matrix material used, the releasing rate of the active agent can be adjusted. Figure 2: In first order release kinetics, the active agent releasing rate is proportional to the concentration of the active agent remains. Whereas, zero-order release kinetics have a constant rate of releasing until all active agent is used up. Monolithic CRM is easy to understand and simple to be fabricated. However, the release of the active agent in this mechanism follows the first order release kinetic has limited its usage, see Figure 2-3.

## 2. 3. 2. 1. 1Reservoir Approach Diffusion CRM

Reservoir approach CRM is characterised by the presence of releasing rate controlling membrane. It is fabricated by coating a membrane outside a monolithic CRM matrix. As such, the monolithic matrix act as the active agent reservoir allowing high amount of active agent to be stored within the matrix and the releasing rate controlling membrane aid in maintaining the releasing rate as to achieve zero order release kinetic, see Figure 2-3. Active agent releasing behaviour of reservoir approach CRM affected the most by the design of the membrane. Type of membrane used, thickness of the membrane, pore size of the membrane, chemistry of the membrane and et cetera. are factors that could be adjusted for different design of delivery matrixes dedicated to different applications.

## 2. 3. 2. 2Dissolution or Degradation Induced CRM

Figure 2: Possible designs for dissolution and degradation CRMsThis category of CRM is designed such that active agents are encapsulated into a slowly disappear delivery matrix. As the delivery matrix disappears, active agents are released to the food. Depending on the material used in designing the delivery matrix, disappearance of matrix material can be classified into physical means of disappearance, also known as dissolution, or chemical means of disappearance, also known as degradation, see Figure 2-4. Dissolution CRM uses material that can slowly dissolve into the food, for example cellulose, poly ethylene glycols, waxes, hydrogenated castor oil and etc. As for degradation CRM, material that can be degraded are selected, for example polylactic acid (PLA), polyglycolic acid (PGA), polycaprolactone (PCL), poly(ortho esters), poly(anhydrides) and etc. Figure 2-5: Bulk erosion degradation behaviour. Its molecular weight is decreasing overtime in the presence of moisture. At its critical molecular weight, the material becomes very porous and allows large amount of active agent to be released. Figure 2-: Surface erosion degradation behaviour. It started to be degraded from the surface. As the material is degraded in a constant speed, the rate of releasing the active agent overtime is constant as well. Dissolution CRM is simple to design as the only concern is the dissolvability of the matrix material. However, degradation mechanism is much complicated to design as different materials behave differently in their degradation processes.

Some materials, i. e. PLA and PGA) degrade homogeneously via bulk erosion, which the material is degrading equally inside out with the same rate of degradation, see Figure 2-5. Other materials, i. e. polyortho esters and polyanhydrides, on the other hand degrade heterogeneously via surface erosion, which the material is degrading from the surface without affecting the material inside, see Figure 2-6. Different degradation behaviours develop different functionalities, delayed release effect can be introduced by using homogeneously degrade material to make the delivery matrix. Whereas, continuous release effect can be introduced by using heterogeneously degrade material to make the delivery matrix.

## 2. 3. 2. 3Other CRMs

Diffusion and degradation induced CRM are two most commonly seen CRMs in the market. Despite that, there are large numbers of other viable CRMs. In this section, some CRMs that are heavily researched are discussed.

## 2. 3. 2. 3. 1Hydrogel Based CRM

Hydrogels are cross-linked polymer that can trap large amount of water without dissolving. Hydrogel can be fabricated in ambient temperature which allowed the incorporation of heat sensitive active agent. In addition, fragile active macromolecules, i. e. proteins, RNAs, DNAs and other biomolecules, could also be incorporated into hydrogel based controlled release food packaging due to the lack of hydrophobic interaction in hydrogel. Also, due to hydrogel’s extreme hydrophilicity, water soluble active agents which are not compatible with conventional plastic packaging, i. e. due to plastic’s hydrophobicity, can be incorporated.[17]Aside of providing a suitable medium for the incorporation of various kinds of active agents, hydrogels are able to be readily modified into different CRMs. For example in its simplest form, it can simply be used as a matrix for containing active agents, similar to the monolithic CRM. By controlling factors such as cross-linking density, water content, porosity and chemical composition of the hydrogel, a desired release profile of the active agent can be achieved. On the other hand, if a degradable hydrogel were to be utilised, a degradation induced mechanism can be produced. On top of designing the hydrogel into diffusion induced or degradation induced CRM, another special class of CRM can be achieved using hydrogel based material is named environmentally responsive CRM. As the name suggests, this type of hydrogel is sensitive to the changes in the environment. Its volume changes in different environments. For instance Fleigge reported the use of poly (N-isopropylacrylamide), a thermo-responsive hydrogel, as an active agent delivery matrix. At ambient temperature, the thermo-responsive hydrogel releases the active agent normally, but at high temperature the hydrogel shrunk and stopped releasing the active agent.[18]Thermo-responsive hydrogel is just one of many environmentally responsive hydrogels that can be designed and fabricated. By altering the chemistry of the hydrogel, the hydrogel can be made sensitive to other environmental factors such as pH, light, carbon dioxide, methane, bacteria and etc. for different food packaging solutions.[18]

## 2. 3. 2. 3. 2Polymer-Active Agent Complex CRM

N-(2-hydroxypropyl)methacrylamide (HPMA) copolymer has been reported to be used as active drug carrier in biomedical application. The active drug carrier was synthesised as such that the drug is bonded with HPMA copolymer via enzymatically degradable oligopeptide spacers, i. e. an enzymatically degradable chemical linkage. In the early 1990s, the active drug carrier was clinically tested and found out that drugs are successfully zero orderly released into the patient’s body after enzymatically degradation of the active drug carrier occurred.[19]Essentially the idea behind this technology is simple, it produces polymer-active agent complex linked by degradable chemical linkages that can be degraded. Although this technology is currently being applied in the biomedical field, but a vast amount of researches are undergoing in most industries to apply this concept and technology in their respective field, including food packaging industry. Industries from all fields of studies are attracted to this technology due to a handful of reasons. Foremost, it provides a higher homogeneity in dispersion of the active agent. As compared to conventional methods, i. e. diffusion and degradation CRMs, this technology allows the active agent to be bonded to the polymer chains in the molecular level. Secondly, good compatibility between various kinds of active agents, i. e. hydrophilic active agent, heat sensitive active agent, proteins, and in various states, e. g. solid, liquid or gas, with the delivery matrix material. Thirdly, higher activeness in the polymer-active agent complex produces. Every polymer-active agent complex is in nano-size, which largely increase its effectiveness in delivering the active agent.[20]Ultimately, this technology is still unknown and unpredictable as researches are still undergoing. However, promising results shown in biomedical field have definitely driven researchers from diverse industries, including food packaging industry, to find out more about this technology.

## 2. 4Food Packaging Polymer Materials

### 2. 4. 1Introduction

Low Density Polyethylene (LDPE) is a semi-crystalline thermoplastic made from monomer ethylene. LDPE was the first of this class to be developed as a packaging material, and was introduced commercially soon after World War II. LDPE is the most commonly used polymer in terms of tonnage and is economical for many applications.[21] These types of polymer are high in molecular weight and have weak Van der Waals forces. However, LDPE has stronger dipole-dipole interaction among molecules. LDPE is made at very high pressure (about 25000 psi) and temperatures above 150°C via free radical polymerization. During the polymerization, many side chain branches also forms. These side chains affect with crystallization and likely to reduce key properties such as stiffness and impact toughness, but they improve clarity and reduce density, which decreases the area cost of films made. [22]Packaging films made from LDPE is naturally soft, flexible and readily stretched. LDPE has good clarity, provides a good barrier to moisture but poor to oxygen barrier properties, also it does not contribute odours or flavours to foods and is readily heat-sealed to itself. These desirable features together with its very low cost per unit area (lowest of any packaging films), have made LDPE the most commonly used plastic packaging material. LDPE major food applications are as waterproof and greaseproof coating for paperboard packaging materials, as adhesive in multilayer structures, as well as films for packaging produce and baked goods.[22]

### 2. 4. 2Structure

LDPE has a chemical structure of ethylene repeating units that branched out from the backbone of the large molecule chain. It has the simplest structure of any polymer, see Figure 2-7. The branches reduce the melting point of small hydrocarbons and prevent them from packing too closely, making it comparatively soft.[22]Figure 2-7: Chemical structure of LDPE2. 4. 3PropertiesLDPE has rather good mechanical properties like good flexibility, high impact strength, and low brittleness temperature and films transparency. The physical properties of LDPE mainly depend on the molecular weight, short chain branching and long chain branching. As the molecular weight increases, strength like tensile, tear and the resistance to environmental stress cracking would improve too. LDPE is partially (40-60%) crystalline solid which melt at 115°C, and has a density of the range 0. 910 to 0. 925 g/cm3.[21]

## 2. 5Multi-layer Food Packaging Films

### 2. 5. 1Introduction

In most food applications, single layer of plastic is not sufficient for a package. In the past, such problem could only be resolved by making laminates or using coatings method. Laminates contained of two or more layers of material bonded with an adhesive or in some cases with a lower-melting plastic. Most laminates uses plastics that are attached to aluminium foil, paper or another plastic to improve the stiffness, toughness and barrier properties to oxygen and water vapour. Commonly, coatings were also used to improve the barrier properties of films and to improve other properties such as heat-stability and slip. While coatings and laminates are still use in a considerably large extent, therefore many combinations are made by co-extrusion process.[23]

## 2. 5. 2Structures

Multi-layer food packaging films uses at least two types of polymers at once to give laminated films. This method requires a separate extruder for the different polymers. This technique allows films to have different properties inside and out, see Figure 2-8. Therefore, an inner layer might confer impermeability, inserted between outer ones which would have greater abrasion resistance. Commonly, it is necessary to have tie-layers which connect the functional layers together. Hence, the films would actually have five layers: outer-tie-central-tie-outer. In addition, the technique does not restraint at 5 layers as 3, 7, 9, 11 layers can be produced with the correct conditions and equipment required such as numbers of barrels for different layers. [23]Figure 28: Cross-section of layered film2. 5. 3PropertiesMulti-layer films concept brought in numerous benefits and improves properties of the packaging films which were processed by co-extrusion. The following are some examples: achieve better control of gas and vapour transmission, introduce slip and stiffness for better handling on packaging machines, integrate scrap between virgin layers, introduce heat-sealable surfaces to films that cannot be suitably heat-sealed, provide more printable surface and improve opacity/colour directly in the films rather than printing on the surface.[22]

## 2. 6Fabrication Techniques of Packaging Films

## 2. 6. 1 Introduction

Multi-cast film process is where thin films of polymer are extruded through a slit onto a chill roll and from there it is move to a series of roll before it is collected and rolled up. The rollers can impart some degree of drawdown to improve the films properties by orientation, thickness of films will be affected if drawdown is used. [23] Commercial uses this process to make thin wrapping films, examples such as cling wrap, food packaging wrap and plastic films use for wrapping books. This process is a substitute method to manufacture plastic films rather than using method like blow films extrusion. In addition, it would lead to better optical property and also faster production rate. The advantage of cast filming is that it can do a multi-layer cast. In other words, different layers of material or polymers can be casted as one film using this method to provide better properties, such as barrier properties or synergistic properties.

## 2. 6. 2Multi-cast Film Processing

In the multi-cast film process, different polymers of pellets or granules are placed in respective hoppers. The polymers are extruded like any other extrusion process. The only difference is that it is in flat films form and the multi-layered production. In the extruder, the different polymers are heated in the respective barrel and the screw rotates then pushes the melted polymer forward into the combining adaptor. In multi-cast film processing, there will be more than one barrel attached to the combining adaptor, thus two or three polymers comes together at the point of films formulation into a single web. This is known as " co-extrusion" process, see Figure 2-9. In the combining adaptor, different polymers laminates over the centre tie layer to form the multi-layer cast films. The extruded multi-layered polymer will then pass through a series of rollers. The first roller the extrudate passes through is the chill roll (shiny smooth surface roll). Chill roll resulted in the extruded polymer to be rapidly cooled. As such, the optical property of material is improved. An example is propylene homopolymer in an air cooled blow film process where a hazy film is produced. This is due to the formation of large crystallites. However, rapid cooling of the chill roll will cause the crystallite to have insufficient time to crystallize and thus bring about clear, soft useful films for packaging. [24] [25]Figure 2-9: Multi-layer cast film extrusionAlso, the thickness will depend on the rolling speed of the chill roll. The faster the rolling speed, the thinner the films will be. The primary function of the die is to form a films or multi-layered film that is uniformly distributed across the width of the die.[26] The major disadvantage of this process is the thickening of the films at the side. This causes non-uniform thickness and thus the sides of the films must be cut off when the cast films process is used. Temperature control plays a very important role in the film casting process. Like any other ordinary extrusion processes, when the temperature used is too high, the polymer will be degraded. Yet, when the temperature used is too low, semi-solid pellets/granules of polymer will be seen on the surface of the films as the polymer is not fully melted and causes surface to be rough and defected. Such situations are not ideal especially, if the films are to be used in the food packaging industry. Therefore it is important that the screw speed and temperature is adjusted to the optimum conditions.

## 2. 7Performance of Fabricated Films

## 2. 7. 1Introduction

Characterisation according to ASTM international material characterisation: " Characterisation describes the features of composition and structure that are of significance for a particular preparation or study of properties or use and reproduction of the material".[27] In other words, the chemical and physical testing is done so as to know the property of the sample. This can be done through a few method of testing that will be further explored later. The LDPE incorporated with linalool film’s property was made known through a sequence of test such as thermal analysis testing, mechanical testing (i. e. tensile test). The antimicrobial effect is also tested so as to test efficiency of linalool incorporated LDPE.[27]

## 2. 7. 2Thermal Analysis

## 2. 7. 2. 1Introduction

The term thermal analysis is commonly used to describe analytical experimental techniques which investigate the behaviour of a sample as a function of temperature. Conventional thermal analysis techniques are differential scanning calorimetry, thermogravimetry, differential thermal analysis, thermomechanical, dynamic mechanical.[28]

## 2. 7. 2. 2Differential Scanning Calorimetry

A Differential Scanning Calorimetry (DSC) analyser measures the energy changes that took place as a sample is heated, cooled or held isothermally, as well as the temperature at which this changes occur. The change in energy provides findings and measurements of the transitions, such as glass transitions, melting temperatures and other more complex events that occur in the sample quantitatively, and to note the temperature where they occur. One of the major and prominent advantages of DSC is that samples are encapsulated easily, generally with little preparation, ready to be placed in the DSC and operate it, so that measurements can be done quickly and easily.[28][29]Heat flux DSC is a simple relatively larger furnace design with a temperature sensor (or multiple sensors) for each of the sample and reference pans situated within the same furnace. Sample and reference pans are located in their required positions and the furnace heated at the pre-programmed heating (or cooling) rate. Basically, when transitions in the sample are encountered a temperature difference is created between sample and reference. As the heating continues beyond the transition state, this difference in temperature decreases as the system reaches equilibrium in reference with the time constant (τ) of the system. It is the difference in the temperature or (Δt) signal that is the basic parameter measured. A typical heat flux DSC analysers can be used from liquid nitrogen temperatures to a maximum of 700°C.[28][29]

## 2. 7. 2. 3Thermogravimetric Analysis

Thermogravimetry Analysis (TGA) is the part of thermal analysis segment which identify and examine the mass change of a sample as a function of temperature in the scanning mode or as a function of time in the isothermal mode. Scanning mode refers to samples being heated at a constant heating rate, known as dynamic measurement, while isothermal mode refers to samples being held at a constant temperature over a period of time. The selection of temperature programme depends on the type of information needed from the sample. TGA is used to characterize the thermal stability and decomposition of materials under multiple of different conditions. Mass changes happen when the sample loses material in one of several different ways or reacts with the surrounding atmosphere. This results in steps and level shown in the TGA curve or peaks in the differential thermogravimetric curve. The mass change characteristics of a material are strongly dependent on the experimental conditions employed. Factors such as the shape and nature of the sample holder, sample mass, volume and physical form, the nature and pressure of the atmosphere in the sample chamber and the scanning rate all have important influence on the characteristics of the recorded TGA curve. [28][29]

## 2. 7. 3Mechanical Analysis

## 2. 7. 3. 1Introduction

Mechanical test provide the knowledge of straightforward mechanical and physical concepts to a material. From this mechanical test, selection of material to application would be easier. Mechanical testing capabilities include tensile testing, impact testing, weldability, compression testing, hardness testing, drop weight and flattening test. All tests have a specific standard procedure to follow. ASTM International is one of the stand which mechanical and physical standards are a guide for proper procedures to determine the physical, mechanical and metallographic properties of a material. Thus from this standard procedure, result can be compare from one to another.[30]

## 2. 7. 3. 2Tensile Properties

Tensile testing is an analytical technique that is used to predict the behaviour of a material under different forms of loading. Several tensile properties such as strength, ductility and elastic properties can be determined with the help of tensile testing. Tensile properties often are measured during the development of new materials and selecting materials for engineering applications.[31]Tensile properties for films are commonly tested using ASTM D882-09. Properties determined by this test method are of value for the identification and characterization of the materials for control and specification purposes. Tensile properties may vary with specimen thickness, method of preparation, speed of testing, type of grips used, and manner of measuring extension.[32]

## 2. 7. 4Antimicrobial Analysis

## 2. 7. 4. 1Introduction

Active packaging systems are dependent on the application of the packaging materials induced with antimicrobial agents. Antimicrobial food packaging reduces or retard the growth of pathogenic and spoilage microorganisms that could be on the packaged food surfaces due to the releasing of antimicrobial components. These systems can contribute to the shelf-life extension, the quality maintenance and the storage stability improvement of packaged foodstuffs.[33]

## 2. 7. 4. 2Total Plate Count

Total Plate Count (TPC) can be used to determine how many bacteria colonies can grow on the agar plate in a certain temperature with certain amount of constant time. This technique is used to estimate the live of aerobic bacteria. The raw meat has to be homogenized with the Phosphate Buffer of 1: 10 ratio. The reason for the Phosphate Buffer is for further dilution of the sample, so as to obtain the desired dilution. The more dilution done, the easier it will be to determine the amount of colony of bacteria per plate. A desired range of colony for counting will be from 25 to 300 colonies. [34]