PHYSICAL AND MECHANICAL PROPERTIES OF FILMS PREPARED USING JACKFRUIT WASTE FLOUR AND POLYVINYL ALCOHOL

by

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LIST OF ABBREVIATIONS

Abbreviations	Description
AD	Anaerobic Digestion
AOAC	Association of Official Agricultural Chemists
ASTM	American Society for Testing and Materials
EB	Elongation at Break
FTIR	Fourier Transform Infrared Spectroscopy
JFRW	Jackfruit Rind Waste
JFSW	Jackfruit Seed Waste
JW	Jackfruit Waste
JWF	Jackfruit Waste Flour
MIDA	Malaysian Investment Development Authority
MSW	Municipal Solid Waste
O	Opacity
OP	Oxygen Permeability
OTR	Oxygen Transmission Rate

PBP	Petroleum Based Plastic
PVOH	Polyvinyl Alcohol
RH	Relative Humidity
TS	Tensile Strength
VFAs	Volatile Fatty Acids
WVP	Water Vapor Permeability

LIST OF SYMBOLS

Symbols	Description
A	Area (m^2)
C	Centigrade
cm	centimeter
gr	gram
h	Hour
Kg	Kilogram
Kj	kilojoule
L	Distance (mm)
mm	Milimeter
MPa	Megapascal
X	Film Tickness (mm)
ΔP	Difference in Partial Vapor Pressure

PENGHASILAN FILEM PEMBUNGKUSAN MAKANAN YANG MESRA ALAM DENGAN MENGGUNAKAN TEPUNG DARI SISA NANGKA DIAMBIL RIND DAN BIJIAN

ABSTRAK

Penggunaan petroleum berasaskan plastik menyebabkan kerosakan serius kepada alam sekitar dan plastik yang mengambil masa yang lama untuk terurai. Oleh itu, kewujudan plastic mesra alam boleh digunakan sebagai penyelesaian masalah yang boleh dipercayai. Objektif kajian ini adalah untuk menghasilkan filem terbiodegradasi dari lebihan tepung nangka (JWF), vinil alcohol poli (PVOH) dan gliserol dan mengkaji pencirian filem dalam sifat- sifat fizikal dan mekanical dan biodegredasi. Tepung sisa nangka (yang diperolehi daripada benih dan "rind") pada mulanya dicirikan untuk komposisi yang mendedahkan mereka untuk merangkumi kandungan protein yang tinggi (16.7%), lemak (4.2%), abu (3.3%) dan karbohidrat (68.5%) dengan tahap kelembapan sebanyak 7.2% (dw). Sebaliknya, Nangka tepung sisa benih juga dicirikan mempunyai protein (11.7%), lemak (0.77), abu (3.3%) dan karbohidrat (80.23%) dengan tahap kelembapan sebanyak 3.9% (dw). Kajian ini telah dijalankan dengan memanipulasi kepekatan berbeza lebihan tepung nangka dan PVOH manakala kepekatan gliserol dimalarkan. Filem- Filem telah diperolehi dengan menggunakan percampuran dan pemutus kaedah sebelum biarkan untuk proses pengeringan. Ciri- ciri filem terbiodegradasikan telah dinilai menggunakan peralatan seperti Testing Machine, Spektroskopi (FTIR) dan mesin Gas Kebolehtelapan. Filem- filem juga mempunyai ciri- ciri dalam ketebalan, kekuatan tegangan, pemanjangan pada takat putus, kelarutan, warna, haba kekuatan meterai dan biodegredasi menggunakan dalam tanah ujian degradasi. Filem pada kepekatan JWF menunjukkan ketebalan tertinggi, kebolehtelapan wap air dan kebolehtelapan oksigen dan tegangan yang paling rendah, pemanjangan pada takat putus, kelarutan dan kekuatan meterai haba. Ciri- ciri ini membuat filem itu cukup baik untuk aplikasi pembungkusan makanan. Ujian FTIR dikenal pasti OH regangan adalah di puncak 3233 cm^{-1} dan CH regangan berada di puncak daripada 2908 cm^{-1} dan 1324 cm^{-1}. Filem- filem juga merendahkan sepenuhnya dalam 5 jam, dan kadar penurunan dianggap tinggi. Walau bagaimanapun, filem itu dengan kepekatan PVOH tinggi mempamerkan tegasan tegangan yang lebih kukuh kerana bahanya. Kesimpulannya, filem yang dicampur dari JWF, PVOH dan gliserol mempunyai aplikasi berpotensi di masa depan untuk digunakan sebagai pembungkusan makanan kerana ia boleh meningkatkan kualiti makanan.

PRODUCING BIODEGRADABLE FOOD PACKAGING FILMS BY UTILIZING JACKFRUIT WASTE FLOUR OBTAINED FROM RIND AND SEED

ABSTRACT

The use of petroleum based plastic cause serious damage to environment and the plastic takes a long time to degrade. Thus, the existence of biodegradable plastic may serve as a promising solution to this problem. The objectives of this study are to produce biodegradable film from Jackfruit waste flour (JWF), poly vinyl alcohol (PVOH) and glycerol and to study the characterization of the film in physical and mechanical properties and biodegradability. Jackfruit rind waste flour (JFRW) were initially characterized for their composition which revealed them to encompass high protein (16.7%), fat (4.2%), ash (3.3%) and carbohydrate (68.5%) contents with a moisture level of 7.2% (d.w.). On the other hand, Jackfruit seed waste flour also were characterized to have protein (11.7%), fat (0.77%), ash (3.3%) and carbohydrate (80.2%) contents with a moisture level of 3.9% (d.w.) This research was conducted by manipulating the different concentration of Jackfruit waste flour and PVOH while the concentration of glycerol was kept constant. The films were obtained by using mixing and casting method before leave for drying process. The characteristic of biodegradable films were evaluated using equipments like Testing Machine, Fourier transform infrared spectroscopy (FTIR) and Gas Permeability machine. The films also characterized in thickness, tensile strength, elongation at break, solubility, color and heat seal strength. The film at high concentration of JWF showed the highest thickness, water vapor permeability and oxygen permeability and the lowest tensile, elongation at break, solubility and heat seal strength. However, the film with high

PVOH concentration exhibit the stronger tensile stress due to its properties. The FTIR test identified O-H stretching was at peak of 3245 cm^{-1} and C-H stretching were at peak of 2908 cm^{-1} and 1324 cm^{-1} respectively. As a conclusion, the blended film from JWF, PVOH and glycerol had potential application in future to be used as food packaging and at conserve the environment.

CHAPTER 1

Introduction

1.1 Overview

Throughout past few decades most of countries worldwide have been paying a serious attention to environmental issues, among which petroleum-based plastic is one of the major ones. One of the main reasons why plastic industry has attracted this much of intense attention is an approximate 5% annual growth in consumption of plastics, which is now exceeding 200 tons (Zhang et al. 2002). This dependence highlights further consequences in the industry if crude oil price soars high, which makes the use of other alternatives to be considered.

With plastic bags as an omnipresent phenomenon in our life, getting rid of them has become a major hassle. Low cost, low density, corrosion resistance, desirable physic-mechanical properties and ease of processing are among the main reasons plastic bags are widely used in day to day activities (Davis, 2006).

"Visual pollution" and "Potential hazards" resulting from the ineffective management and disposal of plastic waste are the two main negative attributes that make plastic bags an unappealing product of today. Visual pollution is referred to the unpleasant appearance and landscape caused by the plastic rubbish scattered in the environment. Potential hazards are referred to long-term and deep-seated environmental problems, which arise when plastic waste is thrown away in the natural environment.

Producing green composites by utilizing degradable wastes and biopolymers have been reported (Kester and Fennema, 1986, Guilbert, 1996; Krochta and De Mulder-Johnston, 1997; Voon et al., 2012) where biodegradable plastics may serve as a promising solution to substitute the role of petroleum in making plastic by a renewable source.

The wastes produced by agricultural sectors also cause serious waste disposal hassles. It is anticipated that there will be wide development prospects and commercial application for tropical fruit waste flour to be mixed with some certain polymers owing their inherent biodegradability properties (Bastioli et al., 1994; Brody and Marsh, 1997; Han and Gennadios, 2005). Jackfruit waste flour is one of the used materials for the production of disintegrated plastics and it comes from renewable resources. However, some poor mechanical properties when biopolymer (such as starch, fish gelatin and so on) need to be blended with plasticizer to reduce its intermolecular forces.

1.2 Problem Statement

It is widely known and complained that the typical Petroleum Based Plastic takes a long time to degrade. Hence, the landfill area will have abundance of PBP waste and lead to another issue including lack of sufficient landfill area and soil intoxication which may easily cause pollution to the environment. When plastic is burned, it can release dioxin which is the most toxic substance.

The aim of this study is to develop a disintegrated polymer film based on different contents of Jackfruit waste flour (JWF) and poly vinyl alcohol (PVOH) while studying their effects on the mechanical properties and biodegradability of JWF and PVOH blends.

1.3 Research Objectives

The main objectives of this research are the following:

i. To fabricate environmentally friendly disintegrated packaging films based on Jack Fruit Waste Flour (JWF) using solution-casting method,

ii. To determine the composition of Jackfruit Waste flour (for rind and seed); and produce, analyze and evaluate the physical and mechanical properties of JWF film

iii. To determine degradation of films under natural soil conditions

1.4 Hypothesis of the Study

This study will be significant in producing disintegrated plastic, which exhibits good mechanical properties and presentable appearance for food packaging purpose. Since the use of plastic in food packaging is undeniable, the finding in this research may be considered for commercialization. This study also may contribute to the reduction of pollution to environment since the petroleum-based plastic caused serious damage to environment. Besides, the effect of other contamination from PBP waste also can be decrease and the lack of landfill area might be resolved since the Biopolymer Based Plastic produce is biodegradable.

This study wishes to provide other alternative material to substitute petroleum role in polymer industry due to depletion in petroleum sources with a renewable source.

CHAPTER 2

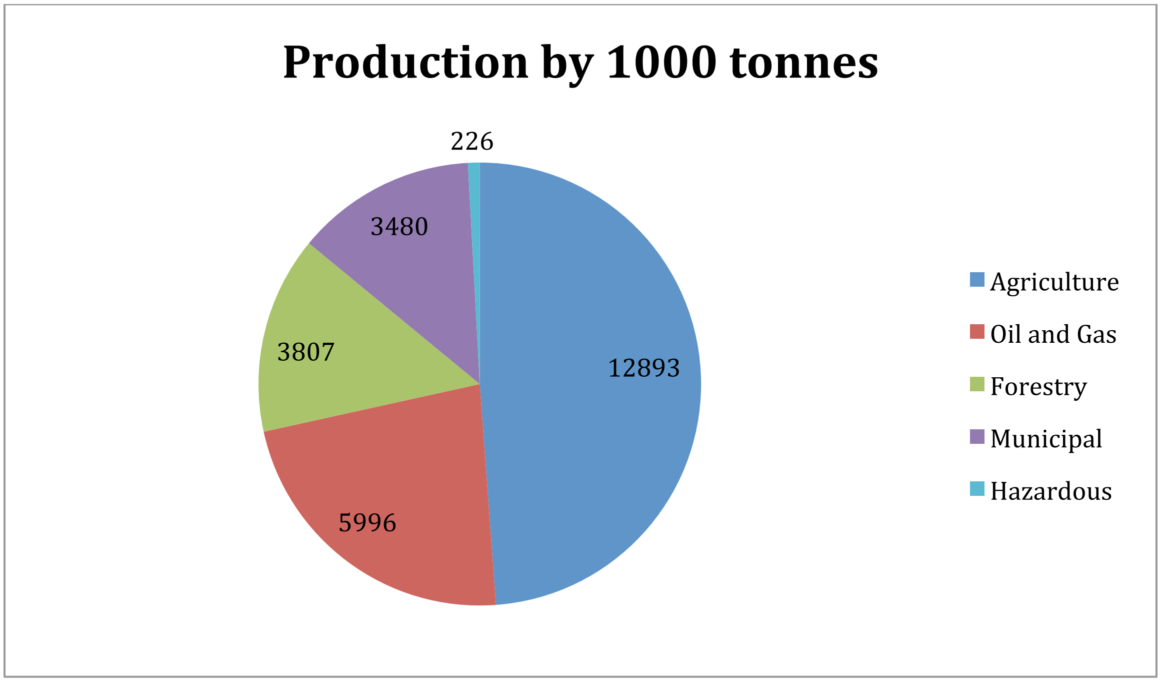
Literature Review

2.1 Agro Waste

Wastage and spoilage of food is an emerging issue that has been given an increased focus in the recent years. Various media, researchers, academicians dependent food companies and society are concerned over waste generated throughout past few years. This can be attributed mainly to three major problems. Foremost is the moral issue of throwing away food when certain categories of living population are starving in the developing world (Stuart, 2009). This wastage can also lead to food insecurity (Nellemann et al., 2009). Secondly, issue of scarcity of natural resources and avaibality of fertile land to produce fresh produce is high (Ridoutt et al., 2010). Lastly, economic crisis and unemployment affects the food sector a lot and if food goes as waste instead of being used for its intended purpose, this can lead to instability too (Ventour, 2008; Lee and Willis, 2010; Buzby et al., 2011). These problems are interlinked with wastage of food, but simply reducing food waste would not solve the problems. For example, it is estimated that 1.3 billion tons of food that are wasted annually (Gustavsson et al., 2011).

Earlier, studies have focused on fruit leading to high percentage waste. For example, 10% in the European retail distribution sector (Gustavsson et al. 2011). Fehr et al. (2002) have reported 8.76% retail waste in Brazilian supermarkets, while waste in the United States retail sector is reported to be 11.4-12% for fresh fruits and 9.7-10% for fresh vegetables (Buzby et al., 2009, 2011). Growing, processing and preparation procedures of food result in the production of different degrees of waste material. The waste material may be seen in the different forms of peel, seed, rind and waste during harvesting, processing industry waste and after processing waste (Joshi and Devrajan, 2008). The non-edible produce of some fruits accounts between %25 ~ %30 of the whole product (Ajila et al., 2010). The waste materials such as peels and seeds produced by the fruit processing have the potential to be successfully used as a source of phytochemicals and antioxidants. The entire tissue of fruits is rich in bioactive compounds and in most cases, the wasted byproducts present similar or even higher contents of antioxidant and antimicrobial compounds than the final produce (Ayala-Zavala et al., 2010). Due to their high value and economically attractive recovery, the new aspects concerning the use of these wastes as byproducts for further exploitation on the production of food additives or supplements with high nutritional value have gained increasing interest. Sugars, minerals, organic acid, dietary fibre and phenolics can highly be seen in the byproducts which have a wide range of action including antitumoral, antiviral, antibacterial, cardioprotective and antimutagenic activities (Jasna et al., 2009). The huge mass of waste not only acts as a host for pests, microorganisms, rats, and insects, but it also has other harmful environmental effects such as pollution of soil by heavy toxic elements, effluent runoff, and the emission of foul odors. Some of the global world problems can be summarized as: Decrease in fossil fuel reserves due to an increase in the world population and energy demand, Global climate change due to the increase of CO_2 emissions, and increase in levels of wastes (solid/liquid) in relation to increase in population among world.

The figure 2.1 shows the production of residual materials in Canada. As it is well highlighted by the chart, the main part of the production goes for agricultural material which is almost 50% of the whole products. This significant percentage suggests the importance of preservation of crops and fruits to reduce the amount of wastage in this sector.



(Figure 2.1 Source from Statistics Canada, Energy and Utilities Board, Alberta Forest Products Assoc., Alberta Agriculture, Alberta Environment, 2004)

2.2 Chemical Composition of fruit wastage

The amount of pollution and characteristics of the waste depend on the food being processed. Chemical composition of the fruit wastes shows that it is a rich source of various nutrients like carbohydrates, proteins, fats, minerals, fibres and etc. Table 2.1 shows the nutrient composition of some of the solid wastes from fruits.

Table 2.1: The nutrient composition of some of the solid wastes from fruits.

Waste	Moisture (%)	Protein (%)	Fat (%)	Ash(%)	Fibre (%)	Carbohydrate (%)
Apple pomace	-	2.99	1.71	1.65	16.16	17.35
Mango seed kernel	8.2	8.50	8.85	3.66	-	74.49
Passion fruit peel	81.9	2.56	0.12	1.47	5.01	-
Banana peel	79.2	0.83	0.78	2.11	1.72	5.00
Jack fruit seeds	64.5	6.60	0.40	1.20	1.50	25.80
Jack seed flour	77.0	2.64	0.28	0.71	1.02	18.12
Jack fruit (Inner and outer portion)	8.5	7.50	11.82	6.50	30.77	14.16

(Source: Maini and Sethi, 2000)

2.3 Importance of Fruit waste

Nowadays, it has been a trend in finding biopolymers as an alternative to synthetic substances which are commonly used in the food and pharmaceutical industry. Epidemiological studies have pointed out that the regular consumption of fruits imparts health benefits, e.g. reduced risk of coronary heart disease and stroke, as well as certain types of cancer. Apart from dietary fibre, these health benefits are mainly attributed to organic micronutrients such as carotenoids, poly-phenols, vitamin C and others.

Flavonoids from fruits are assumed to reduce risks of diseases associated with oxidative stress, including cancer. Apple contains significant amounts of flavonoids with antioxidative potential (Boyer and Liu, 2004). The obtained products and byproducts throughout the minimal processing of the fruits were analyzed for the phytochemical content and antioxidant status. The total phenolics and flavonoid contents were found to be higher in the byproducts as compared to the final products, being more pronounced in mango seeds and peels. These compounds could be responsible for free radical inhibition activity. Many studies have shown that the content of phytochemical compounds is higher in peel and seeds comparing to the edible tissue. Gorinstein et al. (2001) found that the total phenolic compounds in the peels of lemons, oranges, and grapefruits were 15% higher than that of the pulp of these fruits. Peels from apples, peaches, pears as well as yellow and white flesh nectarines were found to contain twice the amount of total phenolic compounds as that contained in fruit pulp (Gorinstein et al., 2001). While the edible pulp of bananas (Musa paradisiaca) contains 232 mg/100 g of dry weight phenolic compounds, about 25% of that present in the peel (Someya et al., 2002).

Other studies in parallel have reported that pomegranate peels contain 249.4 mg/g of phenolic compounds as compared to only 24.4 mg/g phenolic compounds found in the pulp of pomegranates. Apple peels were found to contain up to 3300 mg/100 g of dry weight of phenolic compounds (Wolfe and Liu, 2003). Reports show that the total phenolic compounds of seeds of several fruits, such as mangos, avocados, and jackfruits were higher than that of the edible product; therefore it is believed the byproducts could be a valuable source of phytochemicals (Soong and Barlow, 2004).

In general, a significant 10-fold higher occurrence between the phenolic contents of byproducts than the pulp was reported. To substitute the synthetic food antioxidants by natural ones has increasingly gained attention over the recent years. The antioxidant compounds from waste products of the food industry could be used to prevent the oxidative damage in living systems by scavenging oxygen free radicals, and also to induce the stability of foods by preventing lipid peroxidation (Makris et al., 2007).

Antioxidants are those groups of compounds that have a preventive effect against oxidative damage induced in the body such as degradation of fatty foods resulting in undesirable color changes or rancidity. Free radicals which normally carry a damaging effect on our body are by- products of oxygen consumption by different organs. In spite of being a vital matter for life, oxygen's reaction with other compounds can be detrimental. Free radicals are the result of some oxygen molecules that convert into oxidizing agent. Throughout the process of exchanging the molecules in the bloodstream, oxygen is combined with many different compounds; some of which can cause damage to body tissue. Antioxidants are significant to defend our body against free radical damage (Ismail et al., 2010). Antioxidants are defined by two main types: 1- natural and 2- synthetic (Zheng and Wang, 2011). Naturally occurring antioxidant includes vitamins A and E which are found in various animals and plants and vitamin C which is found in citrus and other fruits and vegetables (Ajila et al., 2007).

Phytochemicals, non-nutritive plant chemicals, possess protective roles in the human body mainly against diseases. Phytochemicals in plants are regarded for physiological and morphological importance which play an important role in plants growth and reproduction and provide protection against pathogens and predators (Bravo, 1998). Also they contribute in the color and sensory characteristics of fruits and vegetables (Alasalvar et al., 2001).

Flavonoids represent a large family of low weight molecular phenolic and according to their structures involve several chemical categories such as flavones, flavonones, isoflavones, isoflavans, flavanol and flavonols (Dinelli et al., 2006; Elizabeth et al., 2007).

Flavonoids and other phenolic compounds, carotenoids and ascorbic acids are important mainly because of their association with the health benefits derived from consuming high levels of fruits and vegetables (Meyers et al., 2003). These phenolics compound have beneficial effects that attribute to their antioxidant activity (Heim et al., 2002). Table 2.2 states the classes of bioactive compound with plant food source and their biological activities.

Table 2.2: Classes of bioactive compound with plant food source and their biological

Compond Class	Plant Food Source	Biological Activities	References
Flavanols	Tea	Anti oxidant, Antiproliferative, Antihypertensive, Anticarsinogenic, Anti thrombotic	Lopez et al., 2001
Flavones	Fruit skin, Red pepper and tomato skin	Anti oxidant, Antiproliferative, Antihypertensive, Anticarsinogenic, Anti thrombotic	Hara et al., 1995
Flavonols	Onion, Olive oil, Berries and Grapefruit	Anti oxidant, Antiproliferative, Antihypertensive, Anticarsinogenic, Anti thrombotic	Stewart et al., 2000
Flavanones	CitrusFruit, Grapefruit, Lemons and Oranges	Anti oxidant, Antiproliferative, Antihypertensive, Anticarsinogenic, Anti thrombotic	Miyake et al., 2000

Isoflavones	Soya bean	Anti oxidant, Antiproliferative, Antihypertensive, Anticarsinogenic, Anti thrombotic	Reinli and Block, 1996
Phenolic Acids	Fruits, Coffee and Cereal bran	Anti inflammatory	Gry et al., 2007
Lignans	Fruits and Vegetables	Esterogenic	Gry et al., 2007
Carotenoids	Tomatoes and Carrots	Anti oxidant, Anti inflammatory	Gry et al., 2007

2.4 Status of fruit waste

The bar graph demonstrates the percentage of food lost by region and stage in value chain. In production stage the least percentage of food loss is related to North America and Oceania region. This percentage experiences a slight drop in Industrial Asia, but has a steady increase moving to the right part of the graph. Processing and distribution section do not play a significant role in the food waste, but in case of handling storage and consumption figures are major. North America and Oceania in comparison to Sub – Saharan Africa exhibit a great percentage of food loss in their consumption section. This major difference between these two regions also suggests the value of food in accordance to its availability and/or scarcity.

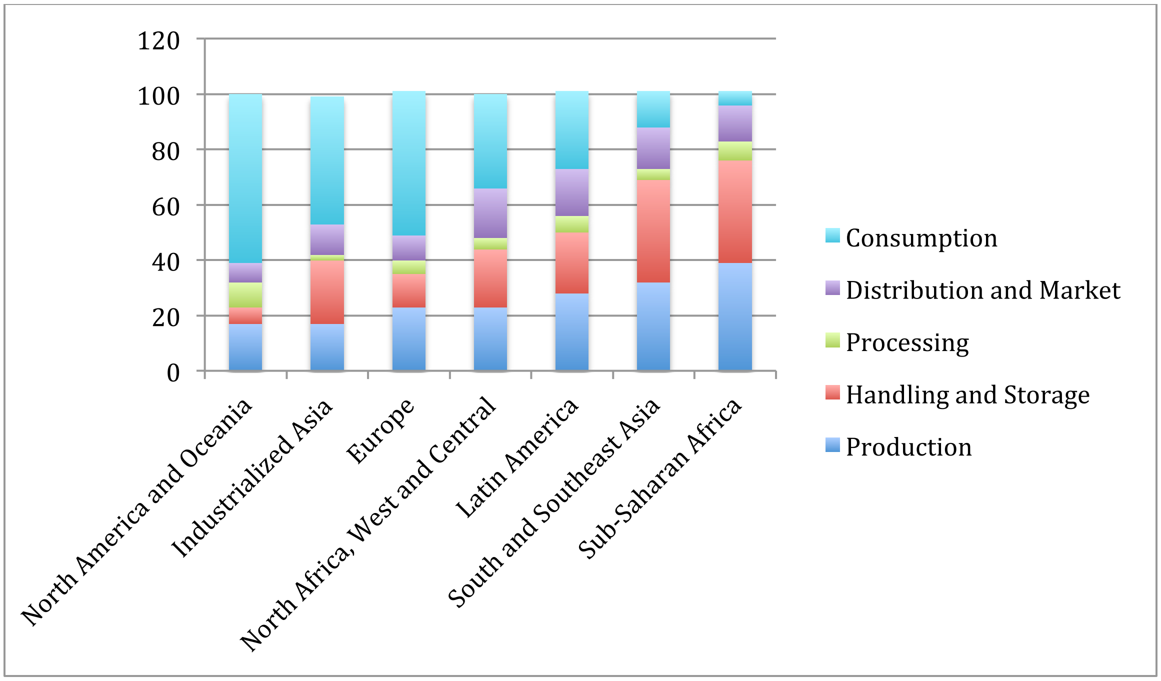


Figure 2.2: Food Lost or Wasted by Region and Stage in Value Chain, 2009. (Percent of Kcal lost and wasted). Source: WRI analysis based on FAO. 2011. Global food losses and food waste- extent, causes and prevention. Rome: UN FAO.

Fruit waste is generally stale or spoilt, not fit for human consumption. This material is usually high in fiber content and is of different size and form. Three fourth of the total solids present are volatile solids. Their biodegradability varies according to the state of hardening and kind of waste material. Carbon to nitrogen ratio varies in all kind of fruits, however for mixed variety it may be around 25-50:1. The origin of biogas can be traced back to the Persians, who discovered that organic matter such as rotting vegetables produced a flammable gas that could be used for other utilizations. Anaerobic digestion of sorted organic wastes from municipal solid waste (MSW), especially food waste, has been regarded as a cost effective technology (Baere, 2000; Edelmann et al., 2000). Methane fermentation is a complex process. The general process of anaerobic digestion occurs in a series of processes like enzymatic hydrolysis, acidogenesis, acetogenesis and methanogenesis (Veeken et al., 2000) where each metabolic stage is assisted by a series of microorganisms. Amongst the four stages, hydrolysis is of great importance; as being the rate limiting stage for fruit waste (Vavilin et al., 1996; Christ, 2000).

Macromolecules such as carbohydrates, proteins, starches, cellulose and etc. are converted to organic acids by the acid-forming microbes. Carbohydrate rich substrates like fruit waste are quicker producers of volatile fatty acids (VFAs) (Mata, 2000) and lead to excess acid accumulation leading to acidity, low pH and process inhibition. So, higher concentration of substrates for fruit waste leads to lowering of pH and thereby produce less biogas. Nevertheless, one of the most important factors affecting anaerobic digestion (AD) process is temperature (Ahring, 1994; Cheunbarn and Pagilla, 2000). Generally AD process is operated under mesophillic or thermophillic conditions in which thermophillic digestion is reported to be a more efficient method (Griffin et al.,1998, Ahring et al., 2001).

2.5 Food packaging

Food packaging accounts 60% of all packaging which is produced in developed countries as well as in Malaysia. The main reason of which is assumed to be the demand of strict food packaging regulations, both to enhance the appearance of product and to increase the product sales. Having fulfilled its duties positively as mentioned before, food packaging has become a major component of all packaging waste which should be regarded as a negative attribute. (Northwood and Oakley-Hill, 1999, Marsh and Bugusu, 2007). Once entered the municipal waste stream food Packaging cannot be ignored;

therefore composting suitable packaging waste is regarded as a viable alternative in the absence of an environmentally sound recycling or re-processing practice of these materials.

The improvement in recycling the packaging material and reducing plastic packaging waste are two odd ends of a momentum, where recycling has improved and reducing plastic packaging waste does not seem to carry any sign of improvement. Consequently a huge bulk of goods made on plastic materials are landfilled, increasing every the problem of municipal waste disposal on an annual basis (Kirwan and Strawbridge, 2003). Where the difficulties associated with collection, identification, sorting, transportation, cleaning and re-processing of plastic packaging materials render the recycling process for these materials to be way uneconomic, landfilling is often practiced as the main disposal method.

Possessing some good attributes such as low cost, low density, resistance to corrosion, desirable physical and mechanical properties and ease of processing, has caused a noticeable increase of plastics and synthetic polymers material application in packaging industry over a period of more than past twenty years (Davis and Song, 2006; Leja and Lewandowicz, 2010). Derived from chemicals extracted from crude oil, plastics that are used in packaging can be thermoplastic or thermosetting (McCarthy, 1993; UNEP, 2009). They have various composition and characteristics, can be mixed with additives such as fillers, plasticizers, colorants and antioxidants to improve the polymer's physical or chemical properties, and usually are coated, printed or laminated with other polymers. In addition, plastic packaging materials are mostly soiled with food leftovers or other organic substances, presenting problems to recycling of these materials and making them impractical. The life span of current commercial landfills has been shortened due to low recycling rates and the high volume of non-degradable plastics. (McCarthy, 1993; Greene J., 2007) resulting in the demand increase of biodegradable plastic packaging materials.

Agricultural mulch, industrial packaging, wrapping, milk sachets, foodservice, personal care, pharmaceuticals, surgical implants, medical devices, recreation and etc. are all examples of several areas where plastic is applied. This application variety requires an immediate action to be taken to shift from conventional plastics to biodegradable ones. Hence, the use of biodegradable polymers derived from renewable resources has received considerable attraction in the recent years. Other findings such as the consumption of microscopic bits of plastic debris by marine animals reported by researchers in a recent science article also urge the aforementioned movement to progress with quick pace (Hoitink and Keener, 1993; Derraik, 2002; Barnes et al. 2009).

To determine the barrier properties of a polymer is of high importance to have the product-shelf life estimated. Product characteristics and its intended end-use are determiners of the package system barrier requirements.

As a general characteristic, plastics show to be relatively permeable to tiny molecules such as gases, water vapor, organic vapors and liquids and they provide a broad range of mass transfer characteristics, ranging from excellent to low barrier value, which is important in the case of food products. As it is highly probable that water vapor and oxygen transfer from the internal or external environments through the polymer wall, they are studied as two main permeants in packaging applications; where if transferred then they will result in a continuous change in product quality and shelf life (Maul, 2005; Lazic et al., 2010).

2.6 Petroleum Based Plastic (PBP)

PBP is a term referring to materials composed of jumbo molecules which made naturally or synthetically are highly modified. According to Muccio (1991), a more precise definition of PBP would be " polymers with a long chain molecules (macromolecules) that are composed of more than thousand repeating units (called monomers) that are linked together in a chain like formation and the number of particular segments repeat is referred as n, the degree of polymerization.

2.6.1 PBP Consumption

a) World Scenario

Today more than 200 million tons of plastic is consumed worldwide. This figure experiences an annual growth of 5 % and involves the largest area where crude oil is consumed (http://en.european-bioplastics.org/press/faq-bioplastics/#define). The aforementioned fact represents the interdependency of crude oil and natural gas price and economic attributes in plastic market and plastic industry. This characteristic was projected in a report published by European countries as an estimated average usage of

100kg plastic per capita (Mulder 1998). This huge number stresses various serious ecological problems that the production and use of fossil based materials pose on earth. As a result a collective effort has been taken to restrict this practice (Sorrentino et al., 2007).

b) In Malaysia

MIDA(2011) reports that Malaysia hosts the most competitive plastic industry among the countries in Asia and the petrochemical industry being an important sector attracts investments of RM 57.2 million in total as at the end of 2008. From an importer of petrochemical, Malaysia has transformed to be an exporter of major petrochemical products today. These products cover a wide range of varieties such as polyolefin, polystyrene, polyvinyl chloride, polybutylene terephthalate, and etc. This industry continues to grow rapidly in Malaysia.

Tremendous economic growth of today's Malaysia results in an increase of population. The increase of population, the developments of community standards and the rapid urbanization accelerates the Municipal Solid Waste (MSW) generation especially in developing countries (Minghua et al., 2009). The estimated population of Malaysia's capital, Kuala Lampur, is about 1.604 million. The quantity of generated waste in Kuala Lumpur experienced a significant upshift from 2,620 tons in 1995 to 4000 tons daily in the year 2007 (Saeed et al., 2008). Economic growth in addition to population and urbanization makes the booming growth of wastes by the industrial pollution and degradation a noticeable urban characteristic in major cities of developing countries (Medina, 2000; Saeed et al., 2008).

2.7 Biodegradation

Temperature (50-70°C), humidity, number and type of microbes will accelerate the biodegradation process. This process is fast only if all three requirements are present. Generally in home or supermarket condition biodegradation occurs very low in comparison to composting. When the condition is changed to industrial composting, biopolymers are converted into biomass, water and CO_2 in about 6-12 weeks (http://en.european-bioplastics.org/press/faq-bioplastics/#define).

2.7.1 Definition of Biodegradability

"No visible, distinguishable or toxic residue" should be left after degradation according to American Society for Testing and Materials's definition of compostable plastic (ASTM Standard D6400, 2004).

a. **Degradable**: If a material undergoes degradation to a specific extent within a given time measured by specific standard testing method then it is categorized as degradable.

b. **Degradation**: It is an irreversible process which leads to a significant change of the structure of material, typically characterized by a loss of properties (e.g. integrity, molecular weight, structure or mechanical strength) and/ or fragmentation. Environmental conditions are effective on degradation process.

c. **Biodegradable:** It is to fall apart into very small particles of packaging or packaging material caused by degradation mechanism.

Synthetizing plastics will make them resistant to degradation; therefore an international drive for the development of biodegradable polymers is fuelled due to their disposal. As the development of these materials continues, novel application for them must be presented by industry. Material usage and final mode of biodegradation remain dependent on the employed composition and processing method. A combined waste management system will be an aide in order to efficiently use, recycle, and dispose of biopolymer materials (Subramanian 2000). It needn't reminded that reduction in the consumption of sources, reuse of existing materials, and recycling of discarded materials must all be born in mind.

Each macromolecule that comprises a polymeric material is referred to as a mer unit. A single mer is called a monomer, while repeating mer units are labeled as polymers. Modern plastic materials use a variety of both renewable and non-renewable attributes as feedstock sources. Plastics that are formed from non-renewable feedstocks are generally petroleum-based. Glass or carbon fibers are used in reinforcing process of this type of plastics (Williams and Wool, 2000).

Three classes are currently being studied by scientists as primary polymer materials. These polymer materials are usually referred to in the general class of plastics by consumers and industry. To increase mechanical properties, and decrease material costs usually filler is present. As results of their smooth surface, conventional plastics are resistant to biodegradation in contact with the soil in which they are disposed. (Aminabhavi et al. 1990; Kim et al., 2005; Ioanna and Demetres 2007)

Microorganisms active within the soil tend to be unable to consume a portion of the plastic, which would, in turn, cause a more rapid breakdown of the supporting matrix. This is due an impenetrable petroleum based matrix which these group of materials present. This matrix is reinforced with carbon or glass fibers.

The second class of polymer materials under consideration is partially degradable. Their design facilitates a more rapid degradation than that of conventional synthetic plastics.

Production of this class of materials typically includes surrounding naturally produced fibers with a conventional (petroleum based) matrix. When disposed of, microorganisms are able to consume the natural macromolecules enabling further degradation.

The final class of polymer materials put in the spotlight by researchers and industry, is a group of plastics designed to be completely biodegradable. The polymer matrix is derived from natural sources (such as starch or microbially grown polymers). Microorganisms consume these materials in their entirety and leave carbon dioxide and water as by-products. (Aminabhavi et al. ,1990; Stevens, 2003).

Biodegradable polymers (those derived from plant sources) begin their lifecycle as renewable resources, usually in the form of starch or cellulose. As Lorcks (1998), Theinsathid et al. (2009) and Avrath (2011) reported, innovative polymer R&D leads to large scale production by plastic converters. The biopolymers are formed into the specific end products and are used by consumers. Ideally, the biopolymer will be disposed in a bio waste collection and later composted. This process will ultimately leave behind carbon dioxide and water; the two environmentally friendly byproducts.

2.7.2 Biodegradable Plastics

1980s was the time when the biodegradable plastics and polymers were first introduced. There are many sources of biodegradable plastics, from synthetic to natural polymers. Natural polymers are accessible in large quantities from renewable resources, while synthetic polymers are produced from non-renewable petroleum sources.

The development of biodegradable plastics can be categorized as follows (Sedlarik et al., 2007):

i. Biopolymers or polymers of natural origins that use polysaccharides such as starch. The formation of Natural polymers occurs in nature during the growth cycles of all organisms. Natural biodegradable polymers are called biopolymers. Polysaccharides, as starch and cellulose, are considered as natural polymers that project the most characteristics of this family. Other natural polymers, as proteins, can be used to produce biodegradable materials. Polysaccharides and proteins are the two main renewable resources of biopolymers. Another resource is lipids. To enhance the mechanical properties of such polymers or to modify their degradation rate, natural polymers often undergo chemical degradation.

ii. Synthetic biodegradable polymers. For instance oil based polymers with a hydrolysable backbone chain such as polyvinyl alcohol is widely used because of its solubility in water. It can be easily biodegraded by microorganisms as well as enzymes (Siddaramaiah et al., 2004).

iii. Chemically or physically modified Synthetic polymers (blends with degradation accelerator additives) to achieve biodegradability.

2.7.3 Different Classes of Natural Polymers

The natural polymers fall into the following broad groups. First group is regarding Polysaccharides - Starch, Cellouse. The second group contains Proteins- Gelatin, Casein, Silk and Wool. In the third group Polysteres are placed, and mainly Polyhyroxyalkanoates. Another group of polymers including Lignin, Shellac, Natural Rubber are defined as the fourth group in this classification.