EFFECT OF PLASTOMER ON MECHANICAL PROPERTIES AND CHARACTERISTICS OF FROZEN CAST POLYPROPYLENE FILM FOR FOOD PACKAGING

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Material) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

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ABSTRAK

Kajian ini memberi tumpuan kepada kesan plastomer pada sifat fizikal dan mekanikal dan ciri-ciri polipropilena cast beku untuk pembungkusan makanan. Polypropylene Cast (CPP) filem yang dihasilkan oleh penyemperitan bersama dikenali sebagai salah satu yang paling popular dan digunakan secara meluas dalam pasaran pembungkusan fleksibel. Walau bagaimanapun, sifat penghabluran tinggi dalam struktur PP semasa pemprosesan, kerapuhan filem meningkat menyebabkan kurang persembahan kekuatan kesan terutamanya pada suhu yang lebih rendah (di bawah 0℃). Beberapa bahan tambahan telah diuji yang digunakan untuk meningkatkan tenaga kesan filem CPP. Objektif kajian ini adalah untuk mengkaji kesan plastomer kepada pengukuran dimensi dan sifat-sifat mekanik multilayer filem CPP dengan ketebalan yang berbeza dan untuk mencirikan filem CPP oleh Scanning Electron Microscopy, X-ray Diffraction dan Fourier Transform Infrared Spektroskopi. Kekuatan kaedah tegangan filem CPP telah meningkat kira-kira 11.6 % ~ 31.7 % dengan kehadiran plastomer. Selain itu, kekuatan kesan telah dipertingkatkan oleh kira-kira 110 %, 90 % dan 37 % masing-masing bagi 60 μm, 70 μm dan 80 μm. Dari kajian ini, pencirian dan keputusan analisis menunjukkan bahawa darjah penghabluran filem CPP selepas menambah plastomer telah bertambah baik dari segi dimensi dan kekuatan. Darjah penghabluran telah diperoleh dibantu dengan plastomer antara 27 % kepada 64 %.

ABSTRACT

This research focuses on the effect of plastomer on mechanical properties and characteristics of frozen cast polypropylene for food packaging. Cast polypropylene (CPP) films produced by co-extrusion are known as one of the most popular and widely used in flexible packaging market. However, the nature of high crystallinity in PP structure during processing, the film brittleness increased as resulted in poor impact strength performances especially at lower temperature (below 0°). Several additives have been used in order to improve the impact energy of CPP films. The objectives of this research are to study the effect of plastomer on dimension measurement and mechanical properties of multilayer CPP films with different thicknesses and to characterize the CPP films by Scanning Electron Microscopy, X-ray Diffraction and Fourier Transform Infrared Spectroscopy. Tensile strength of CPP films has increased about 11.6 %~31.7 % with the presence of plastomer. Besides that, the impact strength was improved by approximately 110 %, 90 % and 37 % for 60 μm, 70 μm and 80 μm respectively. From this research, the characterization and analysis results have shown that the degree of crystallinity of CPP films after adding plastomer has improved in terms of dimension and strength. The degree of crystallinity has raised aided with plastomer between 27 % to 64 %.

DEDICATION

Dedicated to
my beloved father, Tan Boon Wee
my appreciated mother, Oon Suan Kin
and my adored siblings Tan Chia Yi
for giving me moral support, cooperation, encouragement and also understanding.

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LIST OF ABBREVIATIONS

PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
BOPP	-	Biaxial Oriented Polypropylene
DSC	-	Differential scanning calorimetry
XRD	-	X-ray Diffraction
SEM	-	Scanning Electron Microscopy
FTIR	-	Fourier Transform Infrared Spectroscopy
WVTR	-	Water vapour Transmission Rate
HDPE	-	High Density Polyethylene
N-AFR	-	No Air Flow Rate
L-AFR	-	Low Air Flow Rate
M-AFR	-	Medium Air Flow Rate
H-AFR	-	High Air Flow Rate
MD	-	Machine Direction
WAXD	-	Wide Angle X-ray Diffraction
POE	-	Polyolefin
ASTM	-	American Society for Testing and Materials
ISO	-	The International Organization of Standardization
NP	-	No plastomer
WP	-	With plastomer
PE	-	Polyethylene

LIST OF SYMBOLS

±	-	Tolerance
mm	-	Millimeter
g	-	Gram
°C	-	Degree Celsius
kPa	-	Kilo Pascal
MPa	-	Mega Pascal
%	-	Percentage
μm	-	Micrometer
cm^3	-	Centimeter Cube

CHAPTER 1
INTRODUCTION

1.1 Research Background

Packaging is the science, art and technology which act as shield or protecting products for delivery, storage, selling and application. Besides that, the process of design, evaluation, and production of packages can be also referring the packaging. Food packaging is certainly important not only for better aesthetic but also to preserve the food from attack of various pests during storage to consumption by customers. Furthermore, when packaging containing contamination, they will cause the reduction in food quality, the consumption of these foods will cause risk to human health (Somaye, 2012).

Nowadays, various types of polymers are popular for food packaging industries. The most favorable selection of packaging materials especially plastics are suitable for a variety of products from food, beverages, until chemicals and electronic items. This is because, they provide exceptional benefits over other typical materials such as shelf life, cost, safety, convenience in processing and also waste reduction.

Generally, flexible plastic films have comparatively low cost, good moisture and gas barrier properties. Besides that, they can be heat sealed to prevent leakage of contents. Even though they will add up slightly to the weight to the product but they can cover tightly to the structure of the food. Furthermore, they are popular in the packaging industry because they are ease to be handled and convenient.

Among various types of polymers, polypropylene (PP) is the mostly used material for making into packaging films. This is because PP can form a clear glossy film with a high strength and puncture resistance. It also one of the most versatile and economic barrier films ever used in packaging application (Tabassi, 2014). Good optical properties, high tensile strength and puncture resistance can be obtained by oriented crystal structure of polypropylene that appeared as a clear glossy film (Bowditch, 1997). In addition, PP is not easily being affected by the changing in humidity as it has moderate permeability to gases and odors including a higher barrier to water vapors from atmosphere. Therefore, PP films are widely used to pack foods such as biscuits, snack foods, dried foods and frozen foods.

PP films are normally produced through upward blown and film casting process. PP films that produced with cast PP offers good transparency, external gloss properties and incredible versatility. There are few applications using PP films. For example, PP-twist films which can be the substitution for PVC and cellophane. Next, metallisable PP cast films which used as the alternative to Biaxial Orientated Polypropylene (BOPP) for food packaging. Lastly, peelable films used for all kinds of films for ready to eat meal and dairy products like cheese.

1.2 Problem Statement

Polypropylene film is the thermo softening plastic film widely used in food packaging application. Co-extrusion of polymer is the process of extruding two or more materials at the same time through a single die. The materials flow paths in the die are arranged and prepared individually before merge together at the die. The purpose of this process is to form a single structure with multiple layers.

In the co-extrusion process, granules form of raw materials is poured into the extruder. A molten form of thin film is extruded through a slit on to a chill turning roll where the film is rapidly quenched on it. The draw ratios and final film thickness are highly influenced by the speed of the roller. Next, the film passes to the second roller. Finally, the long sheet of polypropylene film will be produced by passing through a system of rollers and is wound onto a roll through calendaring process.

One of the major concerns in the calendaring system is producing film sheet with uniform thickness distribution with tolerances of ±0.005 mm. The thickness of the polypropylene films produced are not uniform. To achieve the uniformity of the film, the dimension of the rollers must be precise and the roll bowing resulting from the high pressure in the nip region should be minimised

Rollers are moving at the same speed, drawing the polypropylene film forwards by calendaring process. But the velocity at each roller are different. Polypropylene films are heated during rolling process. Materials are nipped in to the rollers and thrown out. As the materials get thinner, velocity become faster. If moving fast, it will stretch the film. More stretching occurred will cause the film to be crystalline and become opaque in surface. The nature of high crystallinity in PP structure during processing, the film brittleness increased as resulted in poor impact strength performances especially at lower temperature (below 0°). Several additives have been used in order to improve the impact energy performances of CPP films.

1.3 Objective

1. To study the effect of plastomer on dimensions of multilayer cast polypropylene film of different thicknesses.
2. To study the effect of plastomer on the mechanical properties of multilayer cast polypropylene film of different thicknesses.
3. To characterize the different thicknesses of multilayer cast polypropylene film by using XRD, SEM and FTIR.

1.4 Scope

The effect of plastomer on thickness of multilayer cast polypropylene films will be measured by scanning electron microscopy (SEM). Besides that, the mechanical properties are emphasized on the tensile and impact properties of the cast PP film. Furthermore, the scope also focused on the characterization of the cast polypropylene films. Three different thickness of the samples of cast polypropylene films which are produced through co-extrusion process will be characterized using different material characterization methods. Qualitative information on cast polypropylene film is obtained by Fourier Transform Infrared Spectroscopy (FTIR). X-ray powder diffraction (XRD) is used for determining the crystallinity of the film.

CHAPTER 2

LITERATURE REVIEW

This chapter focuses on the theory of polypropylene, production route of the polypropylene film, and characterization methods involved in the project. The main objective of this chapter is to provide a detailed explanation in a chronological order from the materials and processes used, until the testing and characterization. Besides, previous studies on the development of cast polypropylene films in food packaging industries are also discussed.

2.1 Polypropylene

Polypropylene (PP) is a synthetic resin built up by the polymerization of propylene, which is one of the most versatile thermoplastic polymers available commercially. It is also one of the important family of polyolefin (Encyclopedia Britannica, 2016). The chemical structure of the polypropylene is illustrated in Figure 2.1, while the important remarkable properties that make polypropylene suitable to be compared with other materials are shown in Table 2.1. Generally, thermoplastic polymer become liquid when heated and become solid when cooled. It can be reheated, reshaped and frozen repeatedly.

Polypropylene (PP) is a common semi crystalline polymer that has a good balance of attractive properties which makes it useful for many industrial applications including good heat resistance, chemical, and moisture including low density (0.900 to 0.915 $g/cm^{3)}$, good surface strength and dimensional stability (Foundations of materials science and engineering, 2011). Apart from that, polypropylene also exhibits good mechanical properties with easy processing, low cost and recyclability.

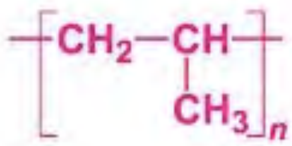

Figure 2.1: Chemical structure of polypropylene.

2.2 Polypropylene Film

Table 2.1 below shows the typical properties of polypropylene, biaxial oriented polypropylene and polyvinyl chloride films. These 3 types of polymers are being compared because they are all benefit appreciably from orientation. PP undergoes biaxial stretching will become tough while PVC are stretched at a temperature above softening point and rapidly cooled down to freeze the orientation of the films. Improving the films orientation able to enhances their physical properties including tensile strength, clarity and stiffness.

Table 2.1: Typical properties of polypropylene (PP), biaxial oriented polypropylene (BOPP) and polyvinyl chloride (PVC) films

Properties	**Polymer**		
	PP	**BOPP**	**PVC**
Tg (°C)	-10	-10	75-105
Tm(°C)	160-175	160-175	212
Heat distortion temperature, at 455kPa (°C)	107-121	-	57-82
Density (g/cm^3)	0.90-0.92	0.90-0.92	1.35-1.41
Tensile modulus (GPa)	1.1-1.5	1.7-2.4	to 4.1
Tensile strength (MPa)	31-43	120-240	10-55
Elongation (%)	500-650	30-150	14-450
WVTR, at 37.9 °C and 95% RH (g µm/m^2 d)	100-300	100-125	750-15,700
O_2 permeability, at 25°C (10^3 cm^3 µm/m^2 d atm)	50-94	37-58	3.7-240

2.2.1 Polypropylene film in food packaging technology

Polypropylene is a linear addition polymer of propylene. In packaging, isotactic resins are being used because PP has the lowest density among commodity plastics which is 0.891 g/cm^3. PP films are highly demand in stiff material that suitable for high-speed packaging applications. Besides that, PP are greatly stiffer than HDPE, and have better improved clarity.

Clarity can be promoted by using copolymer resins including some ethylene units to minimize the crystallinity. On the other hand, the use of nucleating agent enhance transparency by reducing average crystallite size. Barrier properties of PP are equivalent to HDPE. At low temperature, un-oriented PP film have a tendency to be brittle. In many applications, biaxial oriented film (BOPP) is preferred. Orientation will effect the stiffness of the film. PP, especially BOPP, does not heat-seal well. Therefore, in order to make heat-sealable films, it is coextruded with sealants (Handbook of Plastic Film ,2003).

2.3 Production route of Making Polypropylene Film

Basically, there are two popular types of stretch films which are cast stretch film and blown stretch film. Blown film is tough and resilient whereas the cast film is soft and easy to be stretched. Due to differences in the process and rapid quenching at chill roll, cast film can provide better gloss, clarity and soft films if compared to blown films. Through this process, it will minimize the crystalline growth, size and concentration. Besides that, cast film is produced at a higher throughput rate than blown film (Handbook of Troubleshooting Cast Film, 2013). Therefore, cast films is a better choice which has more suitable properties to be produced as food packaging films. Table 2.2 shows the main difference of cast films and blown films.