Redesigning the Coffee Laminate from Aluminum Foil Based Laminate to Metalized Polyethylene Terephthalate Laminate: A Comparative Study

by

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ABSTRACT

The world of flexible laminate producers are becoming extremely competitive day by day and most of the intra industry competition is based on cost advantage. It has been a challenge for such industries to be able to come out innovative packaging material which not only is able to compete on the quality front with the presently used material but also reduce the cost of packaging for their B2B buyers. Against this background this present study was positioned with the main objective to understand and assess whether Metalized BOPET (Bi-axially oriented polyethylene terephthalate) based structure can replace the Aluminum foil based structure in coffee packaging which has been widely used as packaging materials for coffee. The Coffee merchandisers favour aluminium because of its glossy nature (customer attractiveness), good barrier properties and easiness to cut-open the packages while in use by the coffee consumers. This study used secondary survey, primary research and laboratory research as methodology to understand usability of MPET based structure replacing Aluminium based laminates in coffee packaging. It researched out 13 relevant parameters related to applicability of MPET film based structure which allows its comparison with Aluminum foil based structure. This study suggests that MPET based laminate structure like 12µPrintedPET+15µExtrudedPE+12µMPET/15 Mic Ext PE +30µPE can safely be used replacing presently used Aluminum structure like 12µPET+18µPE Extruded+9µAl foil/18µExt PE +45µPE. This MPET based structure would be cost effective and comparatively reduce laminate Cost per square meter of laminate by 31.83 percent over Aluminum based structure. This is a huge saving in all practical purposes. However, in order to take advantage of reduced cost the producer has to keep in mind that shelf life of MPET is lower by 30 days. However, other advantages associated with MPET structure like higher Optical density, better barrier properties in case of OTR, WVTR and Pinhole, particularly in flexed condition, still make MPET extremely good for packaging of coffee. This study also touched upon consumers' preference while switching over from Aluminum to MPET and empirically found that buying of coffee is not at all dependent on material used for packaging. Hence, this study found wisdom in replacing usual Aluminum foil structure with MPET structure and recommended the same to the laminate producers of the world.

Key words: Flexible laminate, coffee packaging, shelf life, consumers' preference, barrier properties, cost effectiveness.

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LIST OF ABBREVIATIONS

PET	Poly Ethylene Terephthalate
BOPET	Biaxially Oriented Poly Ethylene Terephthalate
WVTR	Water Vapor Transmission Rate
OTR	Oxygen Transmission Rate
OD	Optical Density
BOPP	Biaxially Oriented Polypropylene
MD	Machine Direction
TD	Transverse Direction
EVOH	Ethylene vinyl alcohol
B2B	Business to Business
MBOPET	Metalised Biaxially Oriented Poly Ethylene Terephthalate

CHAPTER 1
INTRODUCTION

1.1 Background

Flexible packaging has been in use for a long time now. It is such a mode of packaging which makes it attractive as well as provides protection to the package. There has been constant upgrade of such kind of package in recent years. The customer's satisfaction level has been increasing day by day and to meet those needs there has to be upgrade from time to time. Today we have many clear plastic packaging films. Brandenberger invented the first common clear film 'cellophane' in 1908.By 1908 he developed the first machine for the manufacturing of transparent sheets of regenerated cellulose. By 1912, Brandenberger was making a saleable thin flexible film used in gas masks. The main advantage of the production of cellophane was obtained by E.I. du Pont de Nemours & Co. when the added a moisture barrier layer to the cellophane, in the form of nitrocellulose coating. This allowed better stiffness retention in the cellophane and facilitated use of the film as an overwrap film for foods. Then the coating was further refined to make it heat sealable as well as creating the first readily sealable transparent packaging film. Later on other coatings were applied like PVdC (polyvinylidene chloride) which added oxygen barrier and moisture barrier to the cellophane resulting in the original non-metal barrier film for food packaging.

Figure 1.1 Different polymer based flexible packaging material

Today, we have many polymers such as PE (polyethylene), PP (polypropylene), PET (polyester) and PS (polystyrene) that are used to produce films for packaging various products. The earlier mentioned polymers are used in monolayer format; they are also used in multilayer films produced by co-extrusion and/or lamination process.

Table1.1 Flexible plastic packaging films market in the USA, breakdown of volume sales by material type for the years 2002 and 2007 (in million lb)

Flexible Plastic Packaging Film type	Year	
	2002	2007
Polyethylene	7676.6	9584.3
Polypropylene	1160.3	1449.2
Thermo plastic polyesters	131.2	170.0
Total	8968.1	11203.5

Source: Secondary survey

1.1.1 Innovation for Different Packaging

Innovation has been very rapid in the flexible packaging sector. Time to time various innovative ideas has been introduced in the sector to suit the changing and competitive market environment of the world . In every corner of the world the growth in demand has been accompanied with growing demand for new features and utility packaging like extended product shelf-life, weight reduction and consumer convenience. These demands are creating significant opportunities for flexible packaging producers to bring out innovative packaging ideas which not only increased usability convenience but aesthetic value as well. For example, the stand-up pouches forayed into the traditional beverage packaging and created almost a packaging revolution.

Today's flexible packaging lamination trends are firmly focused on several or all of these key factors, with the overriding objective of lowering production costs to meet consumer demand. One trend is film down gauging to reduce overall packaging weight. However, retaining the desired pack performance, such as stiffness, strength and barrier properties, creates another set of challenges. Tackling these issues head on, producers are incorporating specially-designed oriented films to enhance critical properties. These films are expected to be less costly but without compromise with the packaging qualities.

The table below indicates some of the film properties of common Biaxially oriented films:

Table 1.2 Properties of common Biaxially oriented films

Mechanical Property		Unit	20µm BOPP	12µm BOPET
Tensile Strength	MD	N/mm^2	140	230
	TD	N/mm^2	280	260
Elongation	MD	Percentage	220	110
	TD	Percentage	70	90
Impact strength		Kg/cm	5	5
Tear propagation		g	3.5	3.5
Yield		m^2/kg	55	59
OTR		cc/m^2d	1600	90
WVTR		g/m^2d	6	8
Density		g/cm^3	0.91	1.393

1.1.2 Reasons for using Flexible Packaging

The main reasons for which now-a-days flexible packages are growing popularity are:

- Innovative
- Widely Extendible Into Diverse Product Categories
- Maintains and Indicates Freshness
- Offers Consumer Conveniences
- Provides Reclosure and Dispensing option
- Can be Easily Transported and Stored
- Creates Shelf Appeal
- Enables Visibility of Contents

- Provides Efficient Product to Package Ratios
- Uses less Energy
- Creates Fewer Emissions
- Creates Less Waste In the First Place

1.2 Statement of the problem

In the current market scenario, packaging provides the most important first point of contact by which a company presents its products to consumers and hence packaging material used for the purposed considered to be very important. Innovation in packaging designs and colors has been never ending as brands fights with each other for shelf appeal and space. Key roles of packaging have been to provide eye catching consumer contact, keep the product intact and maximize shelf life with design innovation. However, during the past years the market has not seen much of an innovation in the coffee packaging sectors. Same kind of aluminum based packaging structures has been used over and over again. Understandably, this is mainly due to the different benefits that aluminum foil provides when used as packaging material. In the recent times many packaging film producers intended to replace aluminum foil based film structure with metalized BOPET film structure but restrained because lack of clear understanding in regards to cost comparison , usability comparison and sustainability comparison.

1.3 Objectives of the study

The importance of packaging design as a vehicle for communication and branding is growing in competitive markets for packaged products besides its need for protecting and enhancing the product's commercial value. This research is based on the objective that ,a comparative study of Metalized BOPET (Bi-axially oriented polyethylene terephthalate) which can replace the Aluminum foil in flexible packaging of Coffee package to make it cost effective as well as sustainable. This is kind of a challenge to make the package eco-friendly as well as keep the price of the package low. Based on the above discussion the objectives of the study are as stated below :

Main objective of the study: The main objective of the study is to find out whether Metalized BOPET (Bi-axially oriented polyethylene terephthalate) structure which can replace the Aluminum foil bases structure in coffee packaging.

Sub objectives of the study:

1. To review the various packaging techniques used in coffee

2. To understand consumers' preferences towards coffee packaging material.

2. To perform various laboratory tests to understand relevant properties of Metalized BOPET structure and compare them with Aluminum foil towards usability as coffee packaging material.

3. To show shelf life of the product while using as coffee packaging material.

4. To, finally, suggest whether Metalized BOPET structure can be used as coffee packaging material.

1.4 Scope and Limitation of the study

This study shall focus on cost credential of the packaging and consider such scenarios only. The scope and limitations of this study includes:

1. Review relevant literature on packaging and data from Polyplex (Thailand) Public Company Limited.
2. The study is limited to its conceptual planning.
3. Cost analysis is based on available data from the company.
4. Some of the laboratory testing process (e.g Delamination process) requires long time. This restricted the sample size under test in many cases.

5. The size of the sample for consumers' preference testing also kept at minimum as it was conducted in a small town very near to the laminates producing company and based on convenient sampling.

CHAPTER -2
LITERATURE REVIEW

2.1 Importance of Coffee Packaging in consumer Product and the market trend

Packaging is a necessity for the prevention from contamination of products from the environment but also for the protection of the environment from the products. In addition to marketing, protection and containment, the packaging also enables more efficient distribution and storage of products, which means that the packaging can help to reduce costs and cut lead-times in the supply chain. Tailor-made packaging and product design can also contribute to a reduction of packaging waste.

Figure 2.1 Flexible Packaging requirements

2.2 Shift from Rigid to Flexible Package

It is said that the present days belongs to flexible packaging. Now, there are varieties types of flexible packaging are available in the market place. To name a few: stand-up pouches, retort pouches, spouted pouches etc. These packages are not only good enough to perform its basic job i.e. packaging but at the same time they are performer in enhancing the shelf appeal. In addition to the advantage of better look, flexible packaging is reducing the production cost of the marketers. In recent years we will not see a bottle of coffee in the shelf of a supermarket. The bottles are now given way to flexible pouches which looks attractive and customers also find it easy to carry and use also. The available packages in the market use aluminum foil as the barrier layer for strong moisture protection. It protects the food inside the package for a long time (increase shelf-life) and also from various germs and insects. In past years aluminum has been the main layer used for barrier function, but things have changed now in recent years. A lot of different film technologies are used now-a-days. One such film is oriented film technology.

To the advantage of the marketers the plastic films are being produced by a large number of industrial producers spreading across the globe oriented film technology. The producers are now engaged in producing more bi-axially oriented plastic films. Characteristically these films gets the toughness and yet flexibility because they are stretched in MD (machine direction) and TD (transverse direction) through the manufacturing process. The characteristics that are obtained with bi-axially oriented film meets the demand required for modern film technology for flexible packaging. The various structures of coffee packages available in the market are:

a) 12µPET+7µFoil+40µPE
b) 12µPET+9µFoil+60µPE
c) 12µPET+9µFoil+80µPE

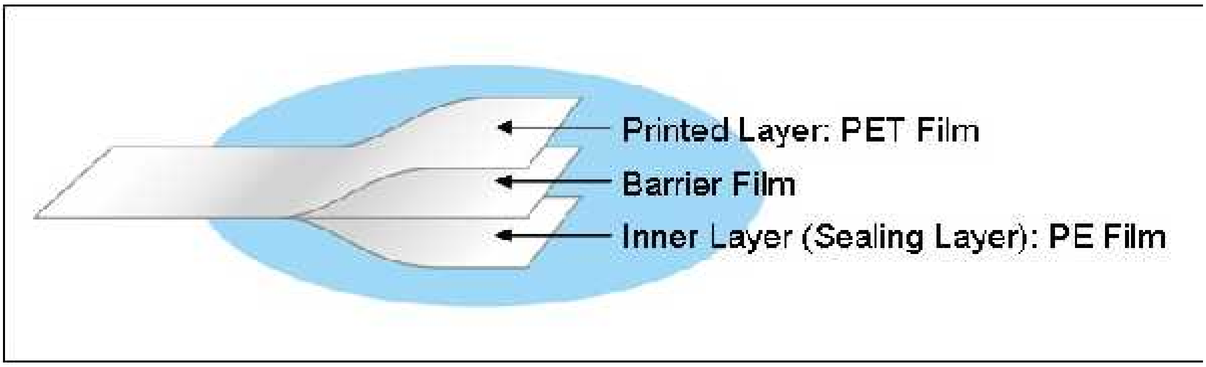


Figure 2.2: Schematic 3D diagram shows the various layers involved in coffee packaging.

2.3 Oriented Film Technology

Many small, medium and large companies are engaged in manufacturing of oriented films. While using the oriented film technology the biaxially oriented films are stretched in both directions i.e. MD (machine direction) & TD (transverse direction) direction so that the barrier characteristics are improved considerably. The improved barrier properties so obtained in biaxially oriented films are considerably attracting the marketers to pack their products through the use of flexible plastic packaging. Flexible packaging, therefore, seems to satisfy the marketers as well as their customers in terms of protective function and the varieties of new designs that can be imparted to the packaging material. Another aspect of attraction is its economic viability. The low cost of producing along with scale economics obtained by the producers allow the economic benefits to be passed on the marketers as well. The packaging material is also coming up clean so far as environment norms are concerned in respective countries where they are used. The product inside in such kind of package will be safe from oxygen, water vapor, others as well as good quality seals. Products when packaged also improve its aesthetic appeal with high lustrous look and excellent printing of product's identity like brand image, tagline etc.

2.3.1 BOPET films

It stands for Bi-axially Oriented Polyethylene Terapthalate. It is a process whereby a continuous cast film sheet is being heated up to bring it to a stretchable temperature and thereafter it is being stretched or oriented in longitudinal direction and then into a horizontal direction. Angle between these two successive orientations is generally 90 degrees. Due to the presence of ester group it is polar in nature and having inherent wettability. (Simplistically, the word wettability indicates the characteristics of low surface tension of a solid surface towards the liquid in contact in terms of its ability to spread over a distance). Technically, corona discharge is required enhancing the wettability of the films in question. So, according to the requirement of the marketers the producer can increase or decrease the wettability of the BOPET film.

Bi-axially oriented polyester films (BOPET) is the latest craze for the plastic film producers. Very quickly the producers adapted this technology resulting production of approximately 2 million tons per year throughout the world which made them the second most frequently used film after BOPP. Trend wise, in the previous years, BOPP films were extensively used in food packaging application and BOPET film mainly used in technical application. However, the recent days has seen proliferation of BOPET film in food packaging as well. The most possible explanation towards this proliferation is that of the improved barrier property of the film which attracted the food producing companies of the world. This has been reflected and recorded in the data base of the plastic film consumption of the packaging industry which clearly showing worldwide growth of 4-5% in every year in terms of consumption.

BOPET film characteristics are listed below:

1. Comparatively high mechanical strength.
2. It is resistant to considerable temperature and chemical reaction.
3. It retains its dimension in different temperature settings.
4. Excellent optical clarity.
5. Good aroma barrier property.
6. Good printability..

This following characteristic above shown gives us an idea about the features for use in different applications.

Some types of BOPET films that are manufactured in the packaging film industry are:

- Normal both side
- One side Corona treated
- One side acrylic coated for improved adhesion
- One side chemical coated for improved adhesion
- Highly shrink Film
- Coated release film

The above mentioned types of BOPET we get from different technical process in factory condition. Different stretching dimensions are used in combination of co extrusion process and subsequent coating of the material. For example, the under process material may be subjected to longitudinal-transverse stretching (MD/TD) process when a certain characteristic is required out of it. However, in certain circumstances longitudinal-transverse-longitudinal (MD/TD/MD) stretching of the in process material can also be used depending upon the requirement of the end users.

2.3.2 Metalized BOPET

Metalized Bi-axially oriented PET has been in the limelight now-a-days because the end users find them economical as well as viable alternative to other form of packaging. The improved barrier properties of the film have attracted many marketers and hence shown inclination for its use in packaging. The great lustrous look of the BOPET in the show case condition in the market place also attract consumers towards this product which is in addition to the attraction resulting from better barrier properties. In the metalizing process a thin layer of aluminum is attracted to the BOPET through a process which is commonly known as vapor disposition process. This process of vapor disposition is a physical process performed in the factory under careful supervision. Other than aluminum metals like nickel or chromium is also in the metallization process of the BOPET film though Aluminum remains the most common. The process of vapour disposition can be stated in the following way. First the selected material is heated to the temperature and allowed to start vaporizing under the vacuum condition. The BOPET polymer film then made to exposed to the vapour which keep on condensing on the cold polymer film surface evenly. Care is taken that the coating deposited on the body of the film is thinner and remains in the range of 0.5 micrometer. Once deposited the film is taken out from vacuum condition and with elapse of time the deposition becomes permanent and the film becomes oriented (PET) film. Polypropylene and polyethylene terephtalate are the most common films used for metallization. Since different types of food wrapping require different barrier properties for the packaging material, so metalizing provide the requisite effectiveness. This effectiveness of packaging material ensure that the shelf life of the packaged substance is extended to the optimum limit by protecting permeability of oxygen and water vapor in to the food inside the package.

In addition to the improved barrier properties the films also comply with the hygienic norms specified by different regulatory agencies of different countries. This has also made the film much usable as foods in direct contact with the film do not get contaminated even after long time exposure. This metallization process provides the much required impermeability inert gases present in the atmosphere. Light energy also cannot pass through the metalized film. The films also pass through the Corona treatment to adjust the surface tension property of the material required for the purpose of use. Films are also subjected to chemical treatment through application of water dispersed polymers) in addition to vacuum aluminum deposition. Films are also made to take different colors like yellow, white, black, red, blue, green, matt or transparent depending on the market requirements. The film thickness is allowed to vary from 7 to 150 μm and width 10-2,200 mm. Biaxially oriented polyethylene terephtalate (BOPET) films, because of its versatile properties are also used for, electrical insulations, and other industrial applications.

2.3.2.1 Properties of metalized BOPET

In a sense metalized films are similar to aluminum foil. Both of them have lustrous and reflective silvery surface. Both of them can block the passage of light, water and oxygen. Therefore, both the films are impermeable to light, water and oxygen. However, the metalized BOPET is expected to be of higher toughness than aluminum foil. Also the material is expected to withstand hot sealing which is much required for a film to be suited for packaging. Interestingly, all these comparative advantage of metalized BOPET is expected to come with comparative low cost advantage. The points that are raised in favour of aluminum film, when compared with aluminum film, have been in terms of better barrier properties. Possibly this is the main reason that metalized BOPET has not been able to replace the Aluminum foil packaging. Of course, barrier properties of the metalized BOPET can be increased with application of ethylene Vinyl Alcohol but the process is costly and therefore does to match up the aluminum foil in terms of cost advantage.

2.4 Difference between BOPP and BOPET

Different sources of plastic packaging journals shows that there have a consumption of about six million tons of BOPP films (as per industry sources) all over the world and out of which biaxially oriented film occupies the lion’s share. BOPP films, therefore, also competes with BOPET to a substantial extent.

However, both of them are used for different packaging purpose. In fact, the application of this kind of film is very diverse and therefore can be used for different packaging purpose including food packaging. The basic difference between these two can be shown in a tabular format placed below. It can be seen from the table that BOPP films has comparatively low tensile strength that BOPET hence can be used for purpose where low strength is required.

Table 2.1 Difference between BOPP and BOPET

BOPP	BOPET
• Lower tensile strength &higher elongation.	• Higher tensile strength & lower elongation.
• Better barrier for moisture.	• Better barrier for moisture & aroma/gas.
• Lower density consequently higher yield.	• Higher density consequently lower yield.
• Low Haze.	• High haze compared to BOPP.
• Poor thermal resistance.	• High thermal resistance.
• Lower machinability if compared to BOPET.	• Better machinability in terms of higher speed in production.
• Lower print but lamination is not required.	• Better printability and lamination is essential.
• Heat sealed BOPP developed recently and can be sealed directly.	• Cannot be heat sealed unless it is laminated.

2.5 Techniques and procedures of checking barrier properties

2.5.1 Oxygen Transmission Rate (OTR) Testing

. Some products which we use in our daily life like coffee, meat, butter etc are oxygen sensitive, therefore these products are required to pack with such material which can maintain the product's freshness and shelf life. On the other hand, the perishable products and their shelf life depend on the surrounding environment that prevails under packaged condition. In any attempt to increase the shelf life of perishable products, therefore, starts with attempt to control the environment inside the package. Controllability of moisture content, oxygen transfer rate and carbon dioxide exchange rate is of utmost importance when the producers or the marketers think of increasing the shelf life of such products by arresting naturally happening deterioration process. In the modern day technology like laser micro-perforating etc are available for controlling the exchange of gases in or out of the packaging material. When they require oxygen transfer rate is known to keep the shelf life to certain duration then these technologies are used to provide a packaging solution by effecting control on the movement of gases inside the package.

2.5.1.1 Measuring OTR

Packaging solution can provide best service to increase the shelf life of the product inside it by setting a balance between the declining oxygen level and increasing carbon dioxide level inside the package. The oxygen transfer rare (OTR) is continuous and can be calculated by assessing the amount of oxygen permeates at a normal rate through the package over a period of time . The unit used for measuring the oxygen transfer rate (OTR) is $cc/m^2/24$ hours ($cc/100in^2/24$ hours). This rate of OTR , therefore , is very important to calculate for the packaging material to understand the capability and usability of the material in a particular condition . As per industry standard a packaging film is considered to high OTR resistant if the OTR rate has a range of approximately 1-10 $cc/m^2/24$ hours. A not so high resistant packaging martial may clock an OTR rate of approximately 1,000 $cc/m^2/24$ hours. However, a low OTR resistant packaging material can have OTR rate of even 10,000 $cc/m^2/24$ hours. The flexible packaging films come with designated approximate base OTR. However this base OTR can be increased with the increase of perforations. More perforations means more flow of oxygen which some packaged products requires badly. As the perishable produce inside the package do respiration the balance of oxygen and carbon dioxide changes. This level of oxygen and carbon dioxide is very important to be understood and which can be influenced by the perforated pattern of the film. The pattern here means size, number, and type of perforations present in the film to help breathing of the package. OTR can also be influenced by the factors like polymerization process, film thickness, type of the product, package volume, head space, and overall weight of the product Interestingly , the combination of all the variable eventually brings out a unique oxygen transmission rate for a packaging material. Also notable here that while the films passes through manufacturing process the pattern, number, and size of perforations vary from film to film and batch to batch and hence OTR will never be exactly the same from one film to another

Figure 2.3 OTR Machine Instrument

2.5.2.2 Yield and Unit Weight

A film's coverage per unit weight is expressed as its Yield. The unit of yield is squire meter per kilogram in metric (or SI) units. It can be seen that reciprocal of yield is unit weight and it is expressed as kilogram per square meter or gram per meter squire (gm /m2). Yield has its significance in film industry.

Yield is estimated for a solid, uncoated film by resin density and average film gauge. Resin density may be changed due to process conditions. It is very important that the yield is measured routinely during the manufacturing process to keep a track of it. While checking, in general, a film is rejected if it deviates from the specified limit with tolerance of ±5%.

2.5.2.3 Optical density

Optical density (OD) is the film’s light blocking capacity and therefore very important in matter of thin film. An instrument, known as transmission densitometer measured OD in the laboratory condition. The optical density (OD) has no unit and is logarithmic. Low OD means that the materials can transmit only a small fraction of light incident on the material.

Transmission densitometer effectively measures the light transmission properties of photographic film. The OD is intimately connected with the thickness of the film and hence from densitometer data can be used to represent the thickness of the aluminum layer of vacuum-metalized films. Layer thickness of the material, therefore, affects important performance-related properties like film barrier, light transmission, and appearance.

2.5.2.3.2 Optical density and metalized films

Metalizing process dimensions and base film characteristics have their impact on the aluminum layer thickness and uniformity. Naturally, therefore, they have effect on optical density of the film. Generally; Optical densities are measured up to two decimal places.

Table 2.2: Light transmission values and optical densities of Metalized film

Optical density	2.00	2.20	2.30	2.40	2.50	3.00
Light transmission in (%)	1.00	0.6	0.5	0.4	0.3	0.1

2.5.2 Film and Package: Step By Step Process Tests

Various tests are executed in the laboratory on the films to understand its effectives for the purpose. These tests are required to understand various properties of the laminate under production. These measurement data are used to understand the usability of the laminate in specific purposes.

2.5.2.1 Specular Gloss

Gloss measurement is one of them and is measured by an instrument named gloss-meter. This simple instrument is fitted with an incandescent light source and a photosensitive receptor which captures light incident on it .

Figure 2.4 Gloss meter instrument

Light made to fall on the film sample on test at a specified angle. A part of the light gets reflected into the photosensitive receptor which is measured. The fraction of light out of the total light incident on the sample is the gloss of the sample. Gloss is an important characteristic of the film and high gloss dimension of the film ensure high marketability.

2.5.2.2 Haze meter

Transparent packaging films are subjected to test their haze properties. The instrument used to measure haze is called Haze meter. In this instrument there is incandescent light source and geometrically arranged photocells. The light is allowed to fall to understand how much actually transmitted and how much got scattered after incidence.

Figure 2.5 Haze meter instrument

The sample, under test, is placed in between the light source and the photocells. After the putting on the light three dimensions are measured 1) amount of light transmitted by the sample, 2) light scattered by the sample and 3) total incident light. These values are noted and percentage of transmitted light scattered out and transmitted are calculated. These two figures, therefore, allow understanding the percentage light that has been scattered by the sample film. Those products, that are packaged in a transparent packaging with the intention that material inside is visible, require sufficient lights to be scattered after incident to provide true visibility effect to the customer.

2.5.2.3 Transmittance tester

Haze meter is used also for testing transmittance. Here, the quantum of light transmitted on translucent materials is measured. Haze meter's lighting source and geometrically arranged photocells are used to understand the ratio between the amounts of light transmitted to the amount retained while passing through the sample under test.

Figure 2.6 Transmittance testing instrument

Transmittance, Opacity and Optical Density can be expressed in the following way.

Opacity = 1 / Transmittance

Optical Density = Common Logarithm (Opacity)

2.5.2.4 Optical Density

Optical Density actually measures the reflectance. It provides the opacity measures of the sample film. In laboratory the sample is tested for reflectance to obtain a contrast ratio. The test is carried out to understand the samples reflectance once against a black material and then against by a white material. In the experiment the incandescent light source and photocell detector are placed on the same side of the sample as shown in the figure above. The back ground will be behind the sample

Figure 2.7 Optical density testing instrument

The optical density will be equal to reflected light by the sample with black background divided by the light reflected by the sample with white background

2.5.2.5 Water-Vapor Transmission

The water vapor transmission rate (WVTR) is an important property of the film which required to be measured carefully. Measurement of WVTR of flexible barrier films is carried out by using an instrument known as infrared diffusometer

Figure 2.8 Infrared diffusometer

The diffusometer is used to create a state of 90% relative humidity at 100°F on one side of a film. This is done by using a heated saturated salt solution. The other side of the film is maintained at 0% relative humidity at 100°F. This is done by a blower releasing a stream of warm dry air. On turning off the source of dry air moisture vapor will be formed on the other side of the sample which eventually permeate the film and pass on to the dry side. This process of moisture building will be continued. The infrared detector fitted on the WVTR machine measures the rate of moisture build up. This rate is actually the WVTR rate. As already stated that this test serves the purpose of understanding the important property i.e moisture barrier of the film produced in factory. However, in the used condition WVTR cannot be measured and it is expected that the factory set WVTR will continue to be retained by the film.

2.5.2.6 Tear-Strength

A simple apparatus is used to measure the tear strength of the sample film. This apparatus tester is fitted with two clamps; one stationary and the other movable. Both the clamps are oriented on a pendulum and the pendulum is fitted in a raised position by some holding arrangement.

Figure 2.9 Tear-Strength apparatus

The pendulum is allowed to be released quickly from one direction to another direction. The travelling route, registered as a arc shaped curve is marked with the help of the scale built in the machine. Next the sample under test is oriented on the machine and in the similar way the pendulum is released which tears in to the sample film clamped into the tester. The tearing pattern in the form of arc is scaled. This scaled arc is designed to be proportional to the tearing strength of the sample. Tear strength is measured in grams. High tearing strength is essential for films as it may indicate the ruggedness of the film with tolerance level when it has been used in practical situation. However, low tear values are also considered necessary for some other purpose of packaging when the actual requirement is low strength packaging.

2.5.2.7 Tensile and Elongation

Figure 2.10 Tensile strength apparatus

The testing machine of clamps to hold the sample, some means of gradually increasing the load on the specimen until it breaks and indicators which show the load and the amount of elongation.

To perform the test, measured, gauged specimens are clamped into the testing machine and stretched until they break.

Tensile strength is usually reported in pounds per inch of width necessary to pull the paper apart. For films, the usual units are pounds per square inch of original cross-sectional area. Tensile strength is quite literally the amount of force necessary to pull a material apart. The elongation is the amount a material will stretch before breaking.

Tensile strength is a most important value for materials used in applications such as heavy-duty bags. A large value for elongation is an index of toughness, since it indicates a material will absorb a large amount of energy before breaking.

2.5.2.8 Gas Transmission

Test specimens are clamped in the 100 cm^2 diffusion cell. Both sides of the cell are initially purged with an oxygen-free carrier gas to remove residual oxygen from the system and de-sorbs oxygen from the sample.

When a stable zero reading has been established, oxygen is introduced into the upper half of the diffusion chamber. The carrier gas continues to flow through the lower half and into the coulometric oxygen detector.

Figure 2.11 Gas transmission tester

After a short interval, the first molecules of oxygen diffusing through the barrier are conveyed by the carrier gas to the detector. As displayed by the graphic recorder, the detector current rises, finally leveling off at a value representative of the equilibrium transmission rate of oxygen through the barrier. It should be noted that this equilibrium transmission rate is independent of the flow rate of the carrier gas.

2.5.2.9 Impact Strength

The pendulum impact tester can be used to measure impact strength of papers, boards and films. An impacting head on the end of a pendulum is swung through an arc into and through sample. Tester has a means of measuring difference between potential energy of pendulum at maximum height in free swing and potential energy of the pendulum after rupture of sample. This difference in energy is defined as impact strength and is reported in units of kilogram-centimeters. It is useful in predicting resistance of a material to breakage from dropping or other quick blows.

A test similar in scope, method and significance is the dart drop test (ASTM-D-1709). Weighted dart is dropped from standard height onto taut sample. Significance and purpose are the same as in the pendulum test.

These tests give an index of material's dynamic strength and approximate what will occur when package is dropped.

Figure 2.12 Impact strength tester

2.5.2.10 Water Vapor Transmission Rate

WVTR (water vapor transmission rate) is the steady state rate at which water vapor permeates through a film at specified conditions of temperature and relative humidity. Values are expressed in g/100 in2/24 hr. in US standard units and g/m2/24 hr. in metric (or SI) units. Test conditions vary, but 90% RH, which is the most common set of conditions reported in North America.

Figure 2.13 WVTR Machine

WVTR, as measurement of film's capability ability to resist moisture transmission, is therefore very important to be understood even while the film is being produced in the factory. Lower WVTR values registered for a sample films indicate better moisture protection and vice versa. This recorded value of WVTR in the WVTR machines is registered at a pre fixed temperature and humidity level. Therefore, it is important to test the WVTR in range of temperature and humidity level.

2.5.2.10.1 Relevance to package performance

Packaging material has to perform differently for different purpose. Sometimes when it is used for packaging of material like coffee, potato chips, pretzels, cookies etc then it is expected that the packaging material will keep the content dry. Similarly, when the packaging material is used to pack moist products like cheese, muffins, chewing gum etc then it is expected that package will not allow them to be dried up. However, both the condition the package and the packaging material have to play a critical role so optimum desired condition is maintained for packaged material. The environment outside the packaging will continuously interact with the packaged material inside the package and moisture exchange process will be commenced until an equilibrium condition is achieved with the environmental relative humidity. If the process of attaining equilibrium is faster then the packaged crispy products like biscuits, chips etc. will be soggy and chewy products will be quickly become hard and dry.

CHAPTER 3
METHODOLOGY AND DATA COLLECTION

3.1 Introduction

This research focuses on the comparative analysis of aluminum foil and (METBOPET) metalized biaxially oriented polyethylene terephthalate towards developing understanding about usability of later as coffee packaging material. In other words, it will show how we can use METPET in coffee packaging without the use of aluminum foil in the barrier layer. If METPET can be used as barrier layer, it will have a huge effect on coffee packaging as this would not only reduce the cost of the package (Per Package) but also sustainable for the environment.

Figure 3.1: The MPET film material

The above pictures show the MPET film that has been used for packaging of smaller coffee pouches in the past years. The MPET has same glossy surface that of aluminum foil and it is difficult to differentiate between the two of them if kept close to one another. In this study we will show how we can design a 200gram package of coffee with MPET as the barrier layer i.e. a standing pouch of coffee packet which can have same or higher property than aluminum foil possesses at a lower cost.

In order to develop understanding in this direction and to make outcome of the research a practical one this study has used primary survey, secondary research as well as laboratory research in respect of the following:

- Research past and present use of Metalized PET in flexible packaging through secondary research.
- Understanding consumers' preferences for coffee packaging material with specific reference to use of metalized foil and aluminum foil as barrier layer through primary research.
- Analyze the economic and sustainability factors through laboratory research.
- Compare the shelf life of the current product available in the market and the new product if used MPET as barrier layer through laboratory research.

- Secondary research on scrutinizing outcome of the research papers on MPET and aluminum foil.

3.1. Primary research

The consumer preference survey was conducted in the Polyplex Company, Thailand for understanding consumers' perception of coffee packaging related to preservation of brew quality and the very important pricing factor associated with packaged coffee powders. The survey questionnaire can be seen in the annexure.

The questionnaire was canvassed to about 100 prospective respondents located at Bowin (location of Polyplex limited production centre). Some of the questionnaires were filled up through interactions with consumers who visited 7-11 stores at Bowin on the spot of their purchase.

3.2 Secondary research

Different journals, articles, studies etc published in the past, available in EBSCO data base, on the use of Metalized PET and aluminum foil in flexible packaging were collected and studied to understand the extant of work in this regard. Indian Institute of Packaging (IIP) library at New Delhi was also searched and relevant material collected to list down the important characteristics of the MBOPET, BOPET and BOP material. The library attached to Polyplex was also searched to understand the parameters having possible effect on coffee packaging quality when MBOPET film structure is used in coffee packaging.

3.3 Laboratory research:

A large extent of this research involved laboratory testing of MBOPET film material in order to establish various parameters associated with MBOPET and aluminum film. The entire laboratory tests were performed in the Polyplex limited's laboratory at Bowin by me under the guidance of my company supervisor. The table below lists out the test and assessment made through laboratory testing and their purpose.

Table 3.4: Parameters effecting packaging quality and Tests /Assessment involved

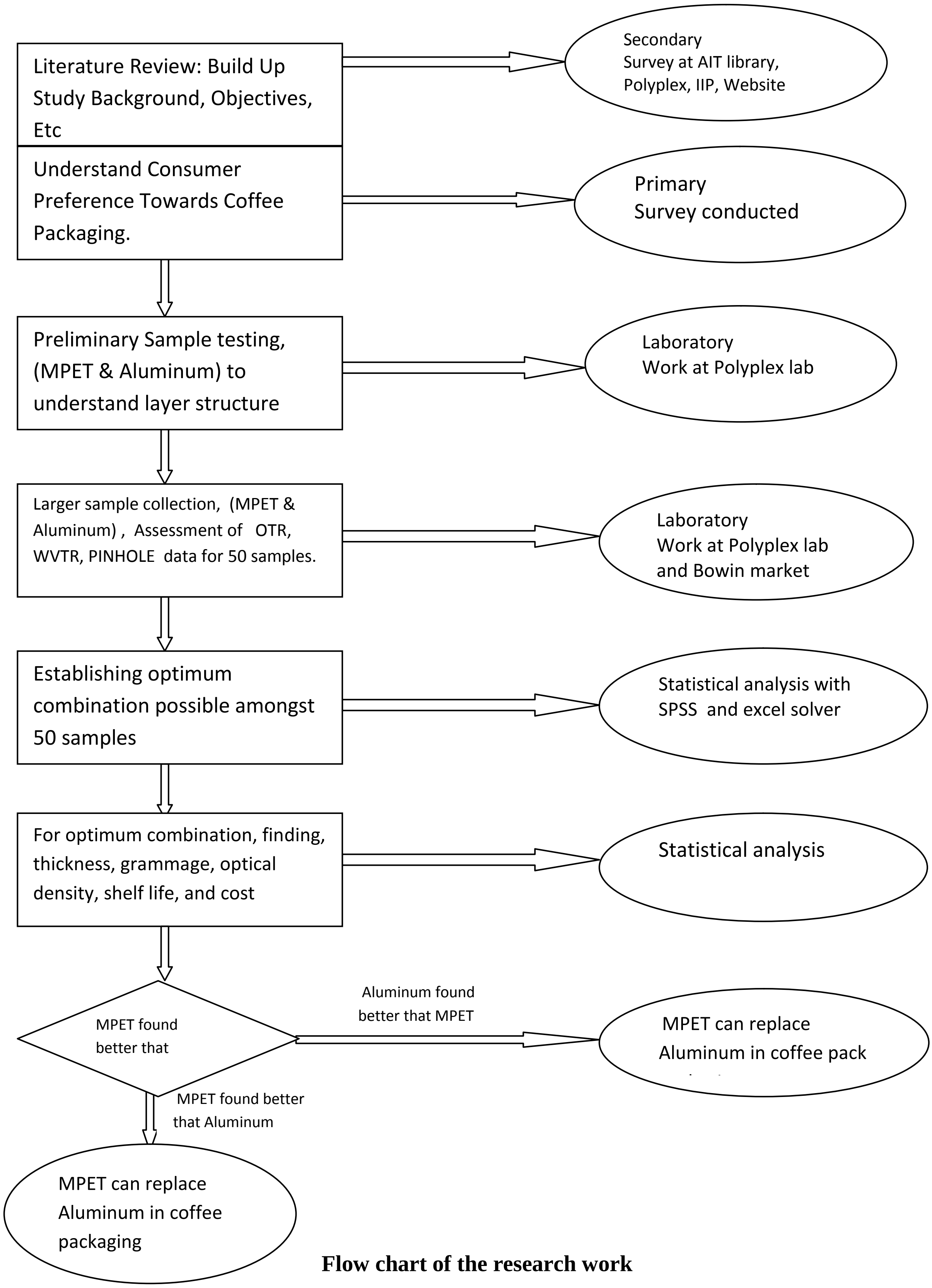
Parameters effecting Packaging quality	Tests /Assessment involved	Purpose	Effects on packaging coffee
Melting Point	Differential Scanning Calorimetry	Thermal strength	Melting point of the material effect coffee preservation
Thickness	Millitron test.	Thickness measurement we can calculate the GSM. (Grammage square meter) and then total Yield of the package.	Give us the idea of the cost of the package
GSM	Assessment	GSM = Thickness * Density	Give us the idea of the cost of the package
Yield (m^2/kg)	Assessment	1/GSM	Yield will give us the idea of the cost of the package
Bond strength	Assessment	Strength	Durability of the package
Oxygen Transfer Rate	OTR machine	For checking the oxygen transmission inside the package	Shelf life of coffee
WVTR	WVTR machine	For checking the moisture transmission inside the package	Shelf life of coffee
Pin Hole	Flex durability or Gelbo Flex test.	Pinholes determines barrier function	More pinholes more possibility of moisture and permeability of oxygen and moisture.

3.4 Data analysis

All the data collected through primary research and laboratory testing was analyzed using relevant statistical analysis. SPSS 21 version was utilized to carry out statistical analysis. Excel solver has been used to solve the maximization problem while finding the best layer combination of different thickness in case of MBOPET and Aluminum film structure.

3.5 Step by Step methodology

The entire works for the study were done in different phases. The laboratory work was done particularly in the Polyplex laboratory as this was the best equipped and sophisticated laboratory in this respect in the entire Thailand. Data analysis and calculations were done in Asian Institute of Technology under the guidance of my supervisor. The different steps involved in the study can be seen in the flow chart below.



Flow chart of the research work

CHAPTER 4
RESULT AND DISCUSSION

4.1 Consumer preference for coffee packaging

The questionnaire was canvassed to about 100 prospective respondents located at Bowin (location of Polyplex limited production centre). Some of the questionnaires were filled up through interactions with consumers who visited 7-11 stores at Bowin, Rayong , Thailand on the spot of their purchase. A total number of 90 questionnaires were returned back or collected and from where 86 could be used. As reveled by table 1 and 2, 41.9 percent of the respondents were of 18-25 years of age followed by 38.4 percent of 36-45 years age group and 14 percent in the 26-35 age group. About 82.6 percent of the respondents were male and the rest (17.6 percent) were female

Table 4.1 : Respondent distribution age (N=86)

Frequency		Valid Percent	Cumulative Percent
18-25	36	41.9	47.7
26-35	12	14.0	61.6
36-45	33	38.4	100.0
Below 17	5	5.8	5.8
Total	86	100.0	

Table 4.2: Respondent distribution by Gender

		Frequency	Valid Percent	Cumulative Percent
Valid	Male	71	82.6	82.6
	Female	15	17.4	100.0
	Total	86	100.0	

One of the basic objectives of the study is to ascertain whether MPET packaging can be used as coffee packaging material and hence the questionnaire survey intended to unearth the factors importantly felt by the coffee lovers while buying coffee from the shops. The factors associated with coffee buying behaviors of the respondents, as revealed in the questionnaire, were used to understand their influence on coffee consumption. To gain a first insight in to the connection between the factors associated with coffee buying behaviors and coffee consumption the bivariate correlation was inventoried and analyzed. The table 3 below shows the result. It can be seen from the table that family consumption of coffee /month is highly correlated with factors like

1) Taste and flavor of coffee,

2) Buyers awareness of different coffee aroma,

3) Heat resistant characteristics of packaging material and

4) Moisture proof characteristics of packaging material.

However, from the same table it can be seen that family consumption of coffee /month is not very much co related with

1) Price of coffee,

2) Packaging material used by a company and

3) Aluminum as material used for coffee packaging .

From the above result we can clearly say that consumers consumes coffee because they love the taste/ flavor of the coffee and because they desire that the flavor /aroma remain intact for long period of time so they are in favor of packaging which allow less moisture to get in inside the package. They also already have a notion that thermal resistance property of packaging material would allow the coffee aroma to be retained. The consumer neither have any special inclination towards aluminum coffee package nor they conscious about any specific packaging material used for the purpose by companies. If , therefore, an alternative packaging material can proposed which can satisfy consumers' requirements in terms of keeping aroma and flavor intact vide provide the same good quality coffee then the customers will be highly satisfied with the new product in the market.

Table 4.3 The Bivariate Correlation between the Independent Variables

Correlations (N=86)

		CCONSUMP	PRICEINFUENCE	FLAVOURINFLUANCE	FLAVAWARELEVEL	ATTNTOPCK	ALUASPKG	MOISTUREPROFFQ	HEATRESISTQ
Family consumption of coffee /month (CCONSUMP)	Pearson Correlation	1	-.056	.796**	.729**	-.705**	-.208	.955**	.908**
	Sig. (2-tailed)		.611	.000	.000	.000	.055	.000	.000
Buying behaviour influenced by price of coffee (PRICEINFUENCE)	Pearson Correlation	-.056	1	-.238*	-.252*	.311**	.490**	-.114	-.079
	Sig. (2-tailed)	.611		.028	.019	.004	.000	.298	.467
Buying influenced by the taste and flavor of coffee (FLAVOURINFLUANCE)	Pearson Correlation	.796**	-.238*	1	.669**	-.701**	-.318**	.806**	.659**
	Sig. (2-tailed)	.000	.028		.000	.000	.003	.000	.000
Awareness of different coffee aroma (FLAVAWARELEVEL)	Pearson Correlation	.729**	-.252*	.669**	1	-.635**	-.341**	.763**	.678**
	Sig. (2-tailed)	.000	.019	.000		.000	.001	.000	.000
	N	86	86	86	86	86	86	86	86
Attention to the coffee packaging material (ATTNTOPCK)	Pearson Correlation	-.705**	.311**	-.701**	-.635**	1	.326**	-.732**	-.604**
	Sig. (2-tailed)	.000	.004	.000	.000		.002	.000	.000
Influence if aluminium material is used as coffee packaging material (ALUASPKG)	Pearson Correlation	-.208	.490**	-.318**	-.341**	.326**	1	-.251*	-.135
	Sig. (2-tailed)	.055	.000	.003	.001	.002		.020	.214
Want packaging material to be moisture proof (MOISTUREPROFFQ)	Pearson Correlation	.955**	-.114	.806**	.763**	-.732**	-.251*	1	.855**
	Sig. (2-tailed)	.000	.298	.000	.000	.000	.020		.000
Want packaging material should be heat resistant (HEATRESISTQ)	Pearson Correlation	.908**	-.079	.659**	.678**	-.604**	-.135	.855**	1
	Sig. (2-tailed)	.000	.467	.000	.000	.000	.214	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.2 Aluminum foil as barrier layer

4.2.1 Melting point: Aluminum foil as barrier layer

For the study of this research work we took a Nestle Nescafe coffee 200 gram packet sample that was having PET+ Aluminum foil+ PE. This retort pouch of coffee had the following three layers of metalized PET acting as the printed layer then aluminum foil as barrier layer and polyethylene respectively used for heat sealing purpose. This data of various layers involved in the packaging we got from DSC (Differential Scanning Calorimetry) test that will be explained below.

Procedures: Firstly we will check the testing procedures required for aluminum foil based structure. Record the data of the test and differentiate later with the MPET based structure.

DSC Test (Differential Scanning Calorimetry): The DSC or the balance test equipment gives us the melting point of the films that are used in the process. When we get the melting point, we can easily find out what is the film or material used. The values we get are in the form of a graph from which we identify the melting point of various materials and we can find out the materials used in the package. The steps that undergo this test are:

Figure 4.1 DSC Test: Pyris Series- DSC 4000

Method Editor–Nescafe Pouch

1. Heat from 50 degree Celsius to 300 degree Celsius at 20 degree Celsius per minute.
2. Hold for 1 minute at 300 degree Celsius.
3. Cool from 300 degree Celsius to 50 degree Celsius at 20 degree Celsius per minute.
4. Hold for 1 minute at 50 degree Celsius.

5. Again heat from 50 degree Celsius to 300 degree Celsius at 20 degree Celsius per minute.
6. Wait till it cools down again.
7. Observe the Graph and take out the sample.

Sample name: Nescafe pouch
Sample weight: 5.3 mg
Operator: Ms.Wichittara /Mr.Abhishek Dutta

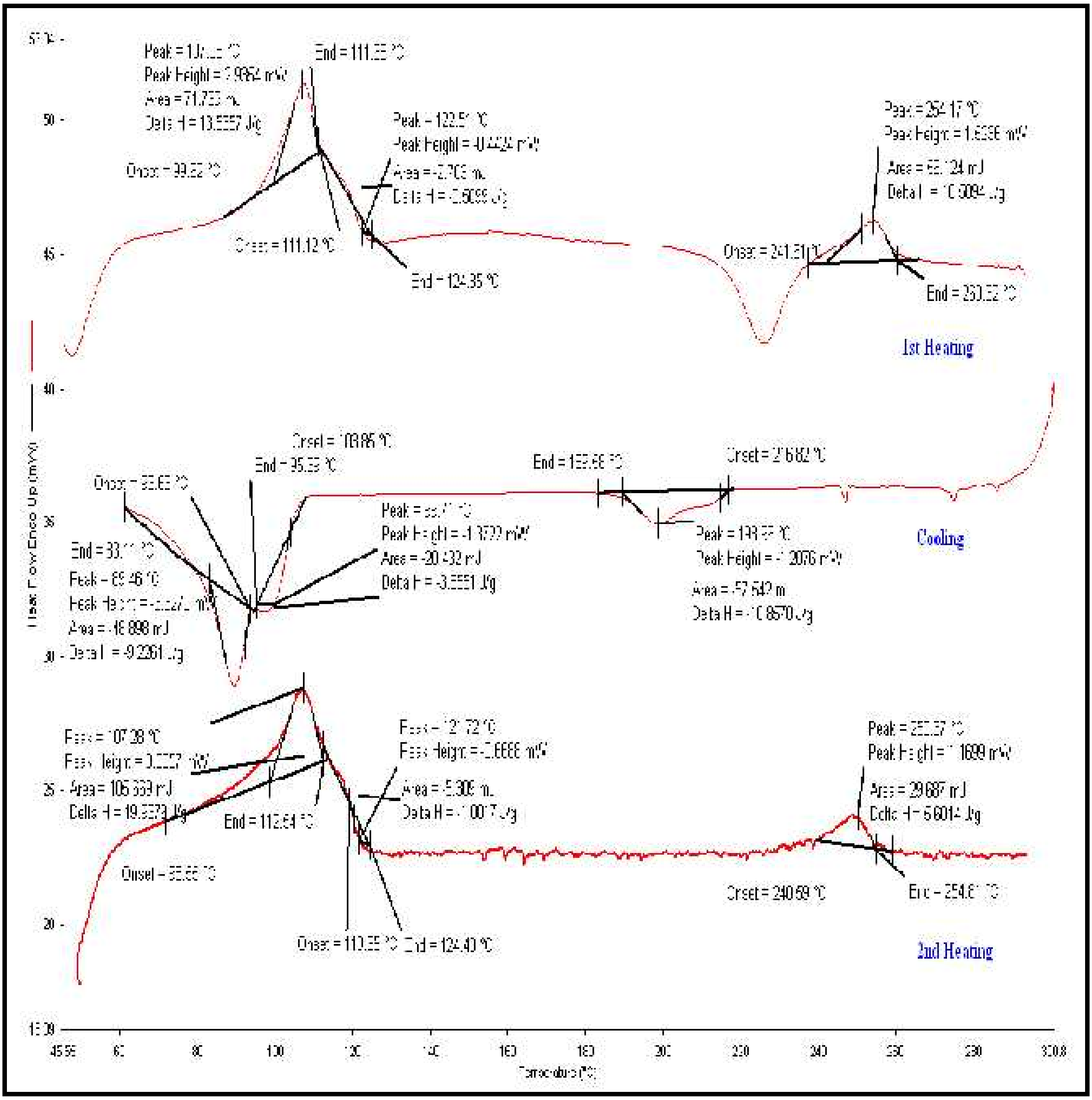


Figure 4.2 Graph shows the melting points at the peak with 107.26°C and 250.37°C

The following melting point is of low density polyethylene and poly ethylene terephthalate respectively.

4.2.2 Thickness: Aluminum foil as barrier layer

After completing the DSC test we went for checking the thickness test which is also called the millitron test.

Millitron Test: This test gives the thickness of the various layers that are involved in the packaging purpose. In this test we take the sample and put it in the millitron machine for checking the thickness in each and every part of the sample.

. **Figure 4.3 Millitron machine for testing thickness**

After the test we found the total thickness of the whole package to be 80µm. The reason we find the thickness because with the help of the thickness measurement we can calculate the GSM. (Grammage square meter) and then total Yield of the package. The calculation of GSM and Yield will give us the idea of the cost of the package which we will talk later in the chapter. Proper attention should be given while testing the thickness as it will directly affect the GSM outcome of the package. After we get the Thickness of the total package we will use the delaminating process.

4.2.3 Understanding the laminate thickness

Delamination Process: Delamination is the process by which we remove one layer from another using ethyl alcohol solution. The process starts with dipping the laminate in ethanol solution for about an hour. But it is difficult to delaminate aluminum foil from the laminate therefore it takes more time maybe 24 hours also.

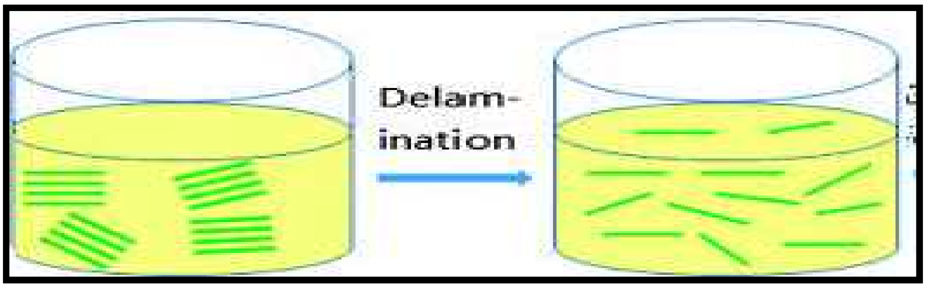


Figure 4.4 Delamination process

Delamination will give us the layer by layer structure of the laminate and we can understand the thickness of each and every layer and therefore calculating how much microns of various materials/ films has been used. For the sample we tested we found the thickness for PET to be 12µm, for aluminum to be 9µm and LDPE to be 45µm. therefore the structure will look like the following **12µPET+15µPE Extruded+9µAl foil+45µLDPE.**

Table 4.4 Result of Total Thickness and GSM

Structure	12µPET+15µPE Extruded+9µAl foil+45µLDPE.	
	Total thickness	Total GSM
Laminate	80.0	90.7
PET Printing	12.0	16.8
Adhesive	-	-
Extruded	15.0	12.9
Foil	8.0	21.6
PE	45.0	39.4
Total	80.0	90.7

Density data used for different Material

PE Transparent	= 0.92
PET Transparent	=0.95
PVC	=1.38
PET	=1.4
Nylon	=1.1
Aluminum foils	= 2.7
CPP0	=0.905
BOPP	=0.905

Calculation for area

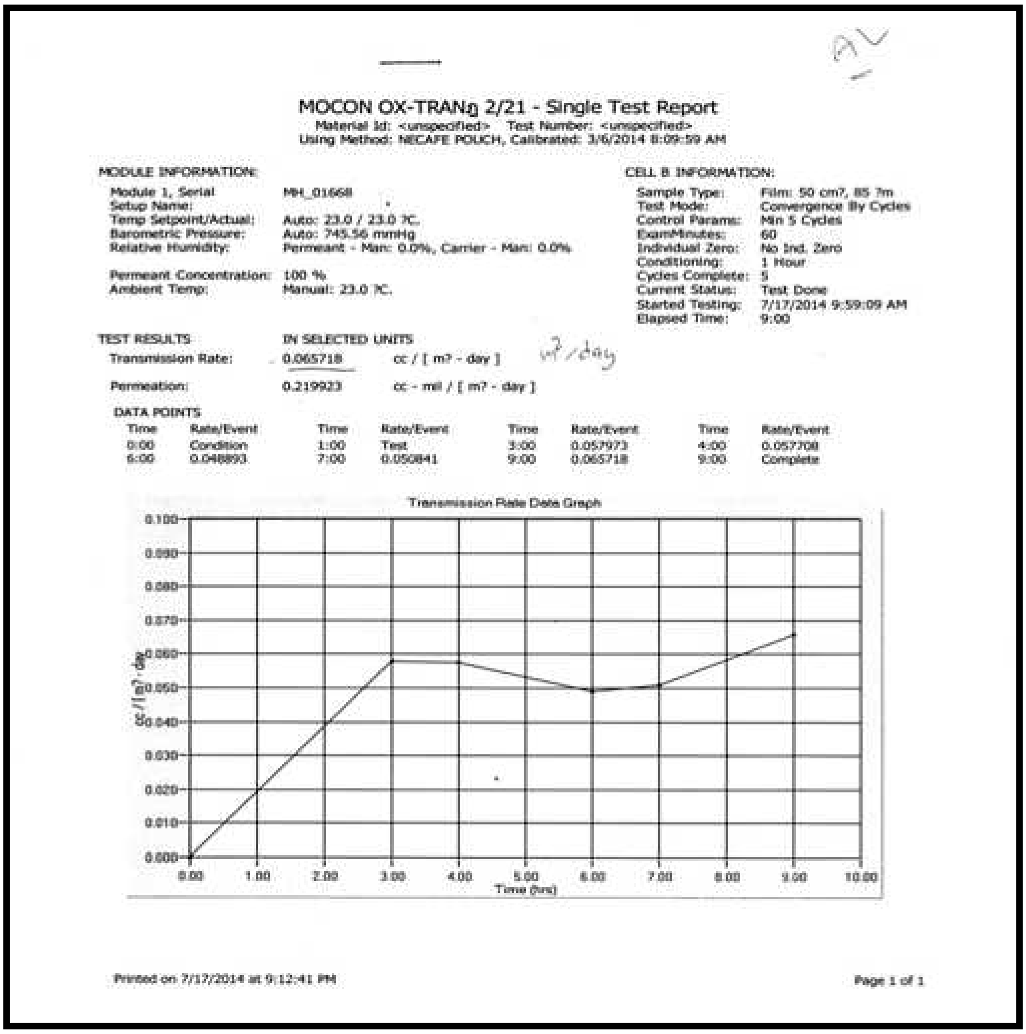
GSM = Thickness * Density
GSM of PET (Example) = 12*1.4= 16.8 gm/m^2
Weight of the sample = 0.2268gms
Length= 5.0 cm
Width =5.0 cm
Therefore Area of the sample =100cm^2

The densities of the materials are fixed, therefore for calculating GSM we have to multiply density and thickness. It is clearly visible from the chart the densities of various materials. For example the density of PET is 1.4g/cm^3 and if we multiply it with PET printed of 12µ we get the GSM of PET to be 16.8 $gram/m^2$. Similarly we calculate for all the materials and therefore we found out the total GSM of the package to be 90.7 GSM or $gram/m^2$., this way we can calculate the GSM of the package. Again if we calculate the GSM of aluminum we get it to be 9 micron of Al foil multiplied by density of aluminum i.e. 2.7g/cm^3. This will be about 24.3 GSM.

Yield of the package calculation: When we think about yield the first thing that comes to mind is the profit obtained from an investment or a return. In here we will talk about the yield of the package that we can find out from the GSM weight of the package. The yield of a package can be found out by Yield = 1/GSM of the package. In the following package above, the yield of barrier layer which is the aluminum foil of 9µ is 1/24.3 i.e.41.15 m^2/kg. The total Yield of the package will be 1/90.7 i.e.11.02m^2/kg.

4.2.4 Oxygen transfer: Aluminum foil as barrier layer

OTR Test: This is a test for checking the oxygen transmission inside the package from the environment. The detail has already been explained in the literature review in chapter 2 .The lesser the transmissions better the barrier property. I tested the OTR for the Nescafe coffee package and we found out the OTR with aluminum foil to be 0.065718 $cc/m^2/day$.



MOCON OX-TRAN® 2/21 - Single Test Report

Material Id: <unspecified> Test Number: <unspecified>
Using Method: NECAFE POUCH, Calibrated: 3/6/2014 8:09:59 AM

MODULE INFORMATION:

Module 1, Serial	MH_01668
Setup Name:	
Temp Setpoint/Actual:	Auto: 23.0 / 23.0 ?C.
Barometric Pressure:	Auto: 745.56 mmHg
Relative Humidity:	Permeant - Man: 0.0%, Carrier - Man: 0.0%
Permeant Concentration:	100 %
Ambient Temp:	Manual: 23.0 ?C.

CELL B INFORMATION:

Sample Type:	Film: 50 cm?, 85 ?m
Test Mode:	Convergence By Cycles
Control Params:	Min 5 Cycles
ExamMinutes:	60
Individual Zero:	No Ind. Zero
Conditioning:	1 Hour
Cycles Complete:	5
Current Status:	Test Done
Started Testing:	7/17/2014 9:59:09 AM
Elapsed Time:	9:00

TEST RESULTS	IN SELECTED UNITS	
Transmission Rate:	0.065718	cc / [m? - day]
Permeation:	0.219923	cc - mil / [m? - day]

DATA POINTS

Time	Rate/Event	Time	Rate/Event	Time	Rate/Event	Time	Rate/Event
0:00	Condition	1:00	Test	3:00	0.057973	4:00	0.057708
6:00	0.048893	7:00	0.050841	9:00	0.065718	9:00	Complete

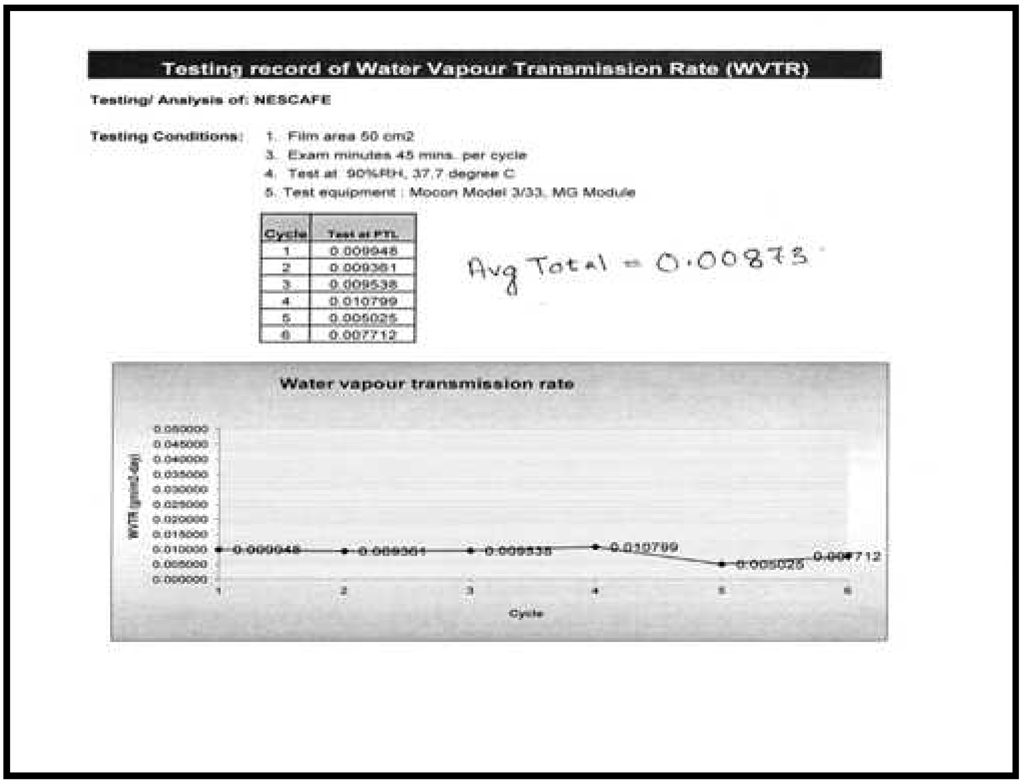
Printed on 7/17/2014 at 9:12:41 PM

Page 1 of 1

Figure 4.5 OTR transmission rate test report

4.2.5 Water Vapour transmission rate: Aluminum foil as barrier layer

WVTR Test: WVTR or Water Vapor Transmission Test is the process by which we check the Water vapor transmission rate into the package from outside the environment. This has already been explained in the literature review in chapter 2. The lesser the transmissions better the barrier property of the film is considered. We in here test the WVTR for the Nescafe coffee package and we found out the WVTR with aluminum foil to be 0.00873 cc/m^2/day.



Testing record of Water Vapour Transmission Rate (WVTR)

Testing/ Analysis of: NESCAFE

Testing Conditions:
1. Film area 50 cm2
3. Exam minutes 45 mins. per cycle
4. Test at 90%RH, 37.7 degree C
5. Test equipment : Mocon Model 3/33, MG Module

Cycle	Test at PTL
1	0.009948
2	0.009361
3	0.009538
4	0.010799
5	0.005025
6	0.007712

Avg Total = 0.00873

Figure 4.6 WVTR transmission rate

4.2.6 Pin hole presence: Aluminum foil as barrier layer

Flex durability or Gelbo Flex Testing: The Gelbo flex tester has been designed for determination of flex resistance of flexible barrier materials by applying repeated strain to the film. We can see that after the strain pin holes are formed. The less number of pinholes determines good barrier function and are determined by use of colored turpentine by allowing it to stain through the pin holes onto white backing.

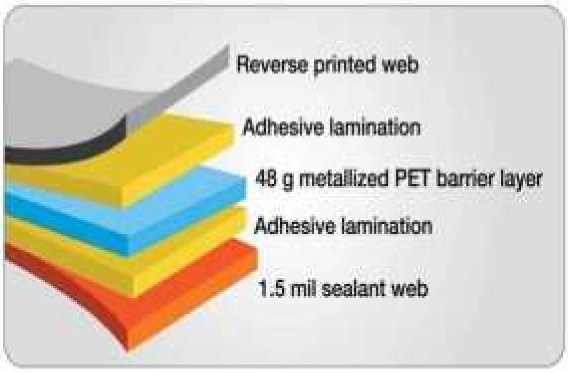
Figure 4.7 Gelbo Tester or Flex Resistance Tester

The materials that will be tested are flexed at standard atmospheric condition. The flexing action consists of a twisting motion combined with a horizontal motion repeatedly twisting and crushing the film. There are 5 pre-programmed test conditions to choose from: Condition A– Full flex for 1 hour (2,700 cycles), Condition B– Full flex for 20 minutes (900 cycles), Condition C– Full flex for 6 minutes (270 cycles), Condition D– Full flex for 20 cycles, Condition E– Partial flex for 20 cycles. The values we get for aluminum foil and MPET when flexed and un-flexed are:

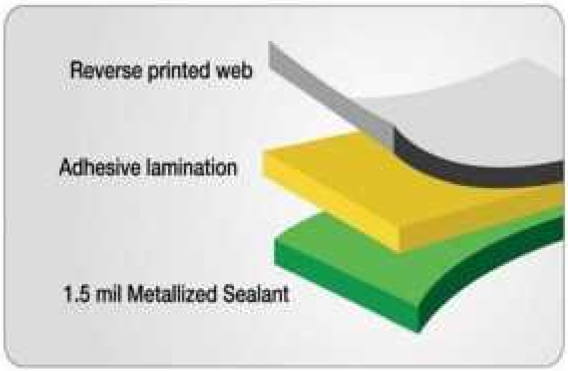
Table 4.5: 3-ply and 2-ply structure

	Test condition	Foil (Un-flexed) 3-ply structure	Foil (Flexed) 3-ply structure	MPET (Flexed) 3-ply structure	MPET (Un-flexed) 3-ply structure
OTR $cc/m^2/day$	50% RH, 74.5°F	0.04	3.5	0.2	0.8

Example of 2-ply layer and 3 ply layer structure



3- Ply Structure



2- Ply Structure

PET (10-12µ)
m-PET (10-12µ)
PE co-extruded film

PET (10-12µ)
PE co-extruded film

Figure 4.8 3-ply and 3-ply structure

The structures are made as per requirements. For example for medical goods packaging it may require 4-ply structure as well. In case of coffee packaging we here use 3-ply structure .These are also called flexible laminate structure. This individual layer gives us the structures as required for various packaging purpose. The individual layer gives an option to develop and combine together to form a barrier for the given package. It generally depends on what kind of things are we packaging. For food packaging mostly used is 3-ply structure.

4.3 MPET as Barrier Layer

Similarly I checked the various procedures for MPET as well. So that we get the comparative evidence of aluminum foil based barrier and metalized PET based barrier properties**.** if MPET is used. The techniques used for checking will be exactly the same as aluminum foil when checked earlier. This will give us an idea about the comparativeness of both the films used for barrier packaging purpose.

4.3.1 Melting point: MPET as barrier layer

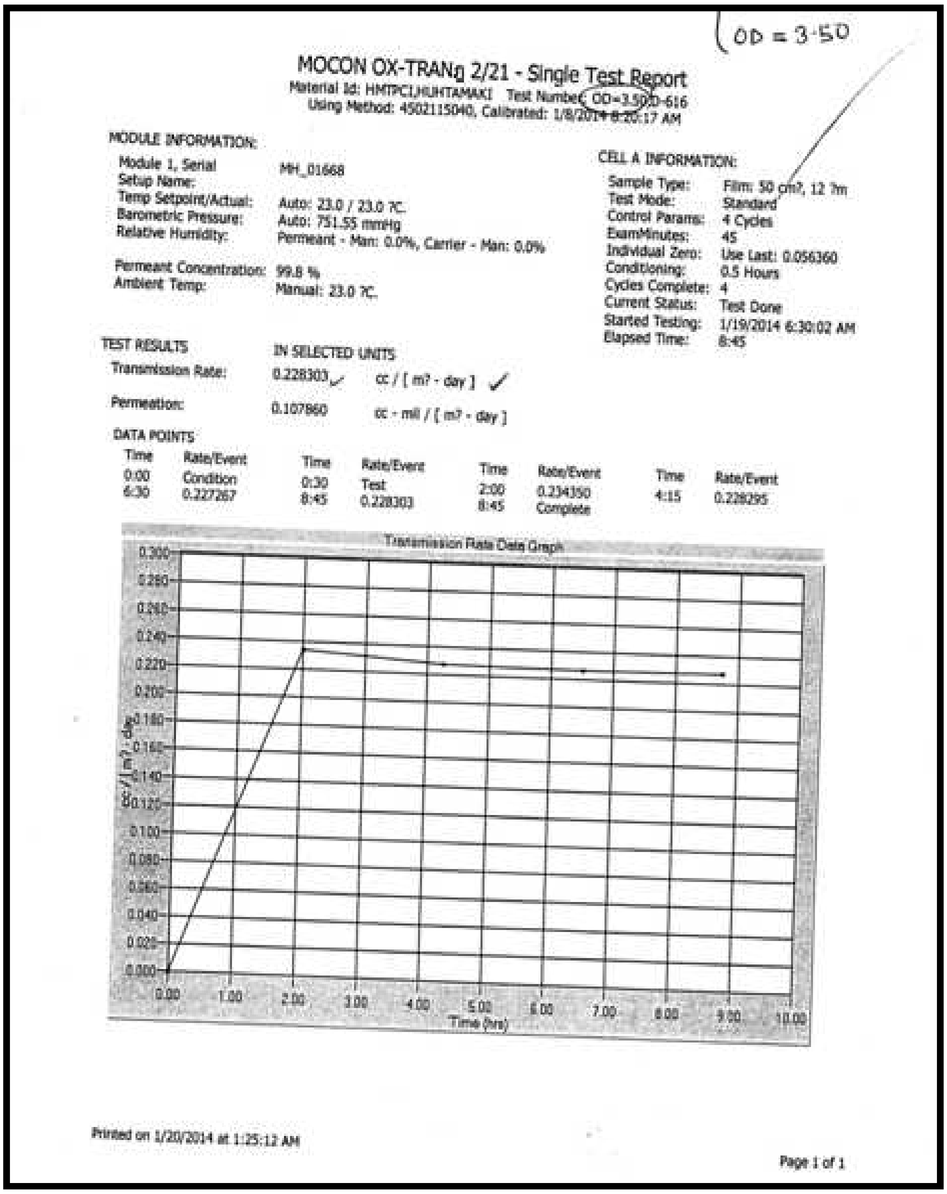
Through DSC test it was ascertained that the melting point of the film . In the similar process as I adopted in case of Aluminum, the structure of the package was ascertained as **12µPrintedPET+18µExtrudedPE+12µMPET+30µPE**. With the help of millitron test we calculate the thickness of the total package and we get the **thickness to be about 72µm** .From here we can easily calculate the GSM of barrier MPET (12µ) and it is about 12 micron of MPET multiplied by the **density of PET i.e. 1.4g/cm^3**, therefore the **GSM is 16.8 gm/m^2.** Now we can calculate the GSM of the whole package and we find out the total GSM to be 77.76gm/m^2. This we calculate by (12µ*1.4+18µ*0.92+12µ*1.4+30µ*0.92) i.e. Thickness multiplied by their densities.

From here we can easily find out the total Yield of the package, we have earlier shown the calculation of Yield while calculating the yield of aluminum foil. Therefore **the yield of the MPET film is 1/16.8 which will be equal to 59.2m^2/kg**. The total yield of the package will be about 1/77.76 i.e. 12.86m^2/kg.

From the Yield calculation of both the aluminum foil and MPET we can see that the yield of MPET is higher than the aluminum foil. Next we tested the Oxygen Transmission Rate for the MPET package and we found the following from the test results.

4.3.2 Oxygen transfer: MPET as barrier layer

OTR Test for MPET: The OTR test for MPET package gives the transmission rate 0.228303 cc/m^2/day. This value is much higher than the OTR value of aluminum foil. This shows that when not flexed the oxygen transmission value of aluminum foil is very good compared to MPET.



OD = 3.50

MOCON OX-TRANg 2/21 - Single Test Report

Material Id: HMTPCI,HUHTAMAKI Test Number: OD=3.50D-616

Using Method: 4502115040, Calibrated: 1/8/2014 8:20:17 AM

MODULE INFORMATION:

Module 1, Serial	MH_01668
Setup Name:	
Temp Setpoint/Actual:	Auto: 23.0 / 23.0 ?C.
Barometric Pressure:	Auto: 751.55 mmHg
Relative Humidity:	Permeant - Man: 0.0%, Carrier - Man: 0.0%
Permeant Concentration:	99.8 %
Ambient Temp:	Manual: 23.0 ?C.

CELL A INFORMATION:

Sample Type:	Film: 50 cm?, 12 ?m
Test Mode:	Standard
Control Params:	4 Cycles
ExamMinutes:	45
Individual Zero:	Use Last: 0.056360
Conditioning:	0.5 Hours
Cycles Complete:	4
Current Status:	Test Done
Started Testing:	1/19/2014 6:30:02 AM
Elapsed Time:	8:45

TEST RESULTS IN SELECTED UNITS

Transmission Rate:	0.228303	cc / [m? - day]
Permeation:	0.107860	cc - mil / [m? - day]

DATA POINTS

Time	Rate/Event	Time	Rate/Event	Time	Rate/Event	Time	Rate/Event
0:00	Condition	0:30	Test	2:00	0.234350	4:15	0.228295
6:30	0.227267	8:45	0.228303	8:45	Complete		

Transmission Rate Data Graph

Printed on 1/20/2014 at 1:25:12 AM

Page 1 of 1

Figure 4.9 OTR value of MPET package

4.3.3 Water vapor transmission rate: MPET as barrier layer

WVTR test for MPET film: After we take the OD=3.5, we calculate the WVTR of the MPET package and found out that the WVTR to be 0.214022 cc/m^2/day**.** We can clearly see that the WVTR transmission value of MPET package is higher than that of Aluminum foil package. This shows aluminum foil has better WVTR value. Results can vary with flexed and un-flexed conditions.

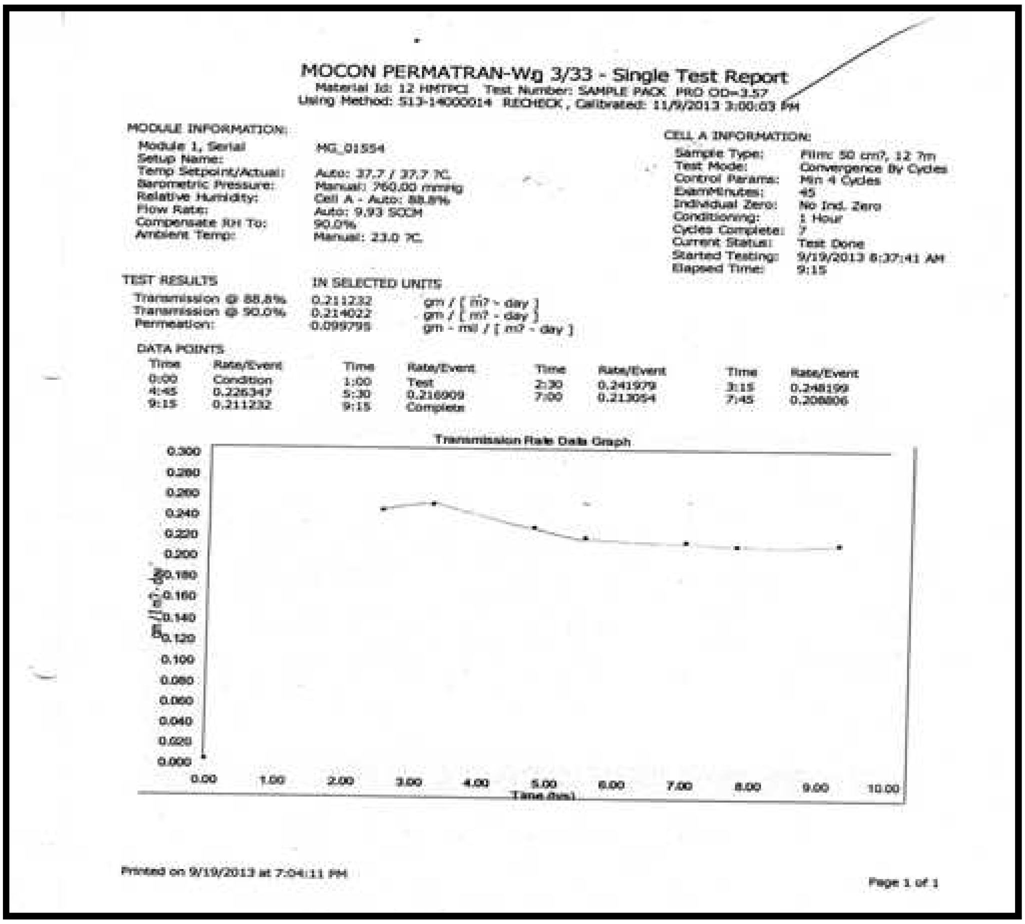


Figure 4.10 WVTR value of MPET package

4.4 Optimum scenario

To further proceed in establishing comparability between MPET and Aluminum film and establish an alternative to aluminum coffee packaging, 51 samples of MPET (flexed) and aluminum (flexed) were collected to test their barrier property in laboratory. Unflexed MPET samples were collected from Polyplex limited and flexed samples from market. The same process was adopted for collecting Aluminum based laminates.

4.4.1 Optimum laminate scenario

Out of the 51 samples collected I picked 10 random sample and were subjected to Delamination test through which layers were removed from another using ethyl alcohol solution. The process starts with dipping the laminate in ethanol solution for about an hour. But it is difficult to delaminate aluminum foil from the laminate therefore it takes more time maybe 24 hours also. Because of paucity of available laboratory time , not all the samples could be subjected to delamination, The result of the delaminating process led to the following result.

Table 4.6: Optimum laminate structure

	Constituents of the film	Thickness in micron	Density	GSM gm/sqm	Resulting structure (MPET Based)
All the 10 samples	PrintedPET	12	1.4	16.8	**12μPrintedPET+15μExtrudedPE+12μMPET/15 Mic Ext PE +30μPE (Total GSM= 88.8**
	Extruded PE	15	0.92	13.8	
	MPET	12	1.4	16.8	
	Ext PE	15	1.4	13.8	
	PE	30	0.92	27.6	
				88.8	
	Constituents of the proposed film	Thickness in micron	Density g/cm3	GSM gm/sqm	**Resulting structure (Al Based) 12μPET+18μPE Extruded+9μAl foil/18 mic Ext PE +45μPE (Total GSM = 115.62 G/M2)**
All the 10 samples	PET	12	1.4	16.8	
	PE	18	0.92	16.56	
	Extruded Al Foil	9	2.7	24.3	
	Ext PE	18	1.4	16.56	
	PE	45	0.92	41.4	
				115.62	

4.4.2 Optimum barrier combination: Aluminium Vs MPET (unflexed)

In order to understand applicability of MPET material as an alternative to aluminum coffee packaging, 51 samples of MPET (flexed) and aluminum (flexed) were tested in the laboratory and following data in respect of OTR, WVTR and Pin Hole were found out. Similarly, tests were also conducted on 51 samples of MPET (unflexed) and aluminum (unflexed) and test data can seen in the following table. Also Arrhenius equation was utilized to understand the Shelf life associated with different samples. The data of Shelf life can also be seen in the tables.

Table 4.7: Laboratory captured data of 51 samples: Aluminum Vs MPET (Unflexd)

Aluminum foil unflexed (9 micron)					Metalized PET un flexed (12 micron)			
Sample no	**Estimated Shelf Life**	**OTR TEST cc/m2/day**	**Pin holes**	**WVTR TEST**	**Estimated Shelf life**	**OTR TEST cc/m2/day**	**Pin Holes**	**WVTR TEST**
1	180	0.0657	230	0.00873	150	**0.2283**	**0.02**	**0.214**
2	180	0.07532	235	0.0123	164	**0.2234**	**0.04**	**0.2655**
3	178	0.034567	276	0.00147	168	**0.2187**	**0.07**	**0.238**
4	180	0.0432	176	0.00678	179	**0.1763**	**0.12**	**0.2765**
5	175	0.0673	145	0.00567	142	**0.3541**	**0.44**	**0.3299**
6	167	0.0448	287	0.00467	156	**0.2654**	**0.09**	**0.1765**
7	180	0.06713	234	0.00433	158	**0.2347**	**0.13**	**0.1459**
8	180	0.0818	346	0.003313	168	**0.2155**	**0.14**	**0.2755**
9	180	0.07165	245	0.00234	145	**0.3287**	**0.17**	**0.2345**
10	180	0.05143	248	0.00861	170	**0.1655**	**0.08**	**0.2188**
11	180	0.0417	234	0.004468	170	**0.1458**	**0.16**	**0.2987**
12	150	0.0313	255	0.00716	172	**0.1765**	**0.19**	**0.3211**
13	180	0.0719	244	0.00618	160	**0.2193**	**0.22**	**0.2998**
14	180	0.09812	234	0.00453	150	**0.2166**	**0.23**	**0.2234**
15	180	0.0765	243	0.00543	150	**0.2133**	**0.34**	**0.2134**
16	180	0.0654	209	0.00653	150	**0.2177**	**0.43**	**0.2154**
17	180	0.0872	205	0.00873	132	**0.2877**	**0.2**	**0.1234**
18	180	0.0123	297	0.00453	129	**0.2987**	**0.34**	**0.1254**

19	157	0.0876	176	0.00541	120	**0.3122**	**0.35**	**0.2345**
20	165	0.0986	187	0.00432	126	**0.2165**	**0.37**	**0.2134**
21	180	0.0764	199	0.00332	134	**0.2188**	**0.36**	**0.1456**
22	180	0.0983	243	0.00542	150	**0.2176**	**0.41**	**0.3421**
23	176	0.0324	166	0.00443	150	**0.2154**	**0.45**	**0.4567**
24	180	0.0335	123	0.0125	150	**0.21**	**0.48**	**0.2166**
25	180	0.0345	166	0.00432	150	**0.2177**	**0.32**	**0.2165**
26	178	0.09865	186	0.00532	150	**0.2134**	**0.31**	**0.3456**
27	180	0.09833	254	0.00872	147	**0.2311**	**0.21**	**0.1123**
28	180	0.0432	247	0.00872	124	**0.3477**	**0.24**	**0.1234**
29	180	0.03321	298	0.00875	176	**0.1267**	**0.26**	**0.1145**
30	180	0.0432	187	0.00873	160	**0.2134**	**0.25**	**0.1165**
31	180	0.0754	144	0.00871	160	**0.2144**	**0.28**	**0.1875**
32	156	0.0874	234	0.00876	160	**0.2166**	**0.29**	**0.2166**
33	177	0.0564	245	0.008993	173	**0.1345**	**0.288**	**0.214**
34	180	0.0432	276	0.00654	174	**0.1455**	**0.23**	**0.2165**
35	180	0.04432	298	0.00543	176	**0.1556**	**0.23**	**0.2188**
36	178	0.0213	236	0.006554	177	**0.1779**	**0.25**	**0.2199**
37	180	0.0342	201	0.00443	180	**0.1234**	**0.26**	**0.2155**
38	180	0.02243	288	0.00854	123	**0.3422**	**0.29**	**0.2165**
39	180	0.03213	218	0.00853	150	**0.2188**	**0.12**	**0.2199**
40	180	0.02134	276	0.00832	132	**0.3566**	**0.15**	**0.2187**
41	180	0.06543	288	0.00821	150	**0.2199**	**0.45**	**0.2166**
42	177	0.03215	234	0.00832	168	**0.1877**	**0.12**	**0.2187**
43	180	0.04322	256	0.00843	168	**0.1866**	**0.22**	**0.2166**

44	180	0.03211	214	0.00652	160	**0.1987**	**0.25**	**0.2234**
45	180	0.02322	213	0.00819	155	**0.1566**	**0.27**	**0.2175**
46	180	0.02155	216	0.00765	150	**0.2134**	**0.29**	**0.21744**
47	188	0.03212	266	0.00987	144	**0.2345**	**0.21**	**0.2165**
48	180	0.02133	270	0.00983	150	**0.2187**	**0.34**	**0.2348**
49	180	0.01266	156	0.00769	150	**0.2187**	**0.33**	**0.2111**
50	180	0.02134	176	0.00872	152	**0.2165**	**0.43**	**0.2113**
51	180	0.02134	175	0.00872	**151**	**0.2164**	**0.43**	**0.2113**

Table 4.8 : Descriptive Statistics Aluminium foil unflexed

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
SHELF LIFE	51	38.0000	150.0000	188.0000	177.686275	.9416257	6.7245526	45.220
OTR	51	.0864	.0123	.0987	.051993	.0036367	.0259710	.001
PINHOLE	51	223.00	123.00	346.00	228.2353	6.64634	47.46434	2252.864
WVTR	51	.0110	.0015	.0125	.006917	.0003310	.0023639	.000
Valid N (listwise)	51							

Table 4.9 : Descriptive Statistics: MPET unflexed

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
SHELFLIFEMU	51	60.00	120.00	180.00	154.0000	15.41428	237.600
OTR	51	.2332	.1234	.3566	.221180	.0561702	.003
PINHOLE	51	.46	.02	.48	.2578	.11577	.013
WVTR	51	.3444	.1123	.4567	.222991	.0641902	.004
Valid N (listwise)	51						

In order to understand the relationship between the variables involved in 51 sample test result, I used exponential dependency relationship since it is evident that the data are randomly recurring in independent event sequence (ref table 4.5 b). So exponential equation Y= $e^{a\ +b\ +c}$ + Constant was considered.

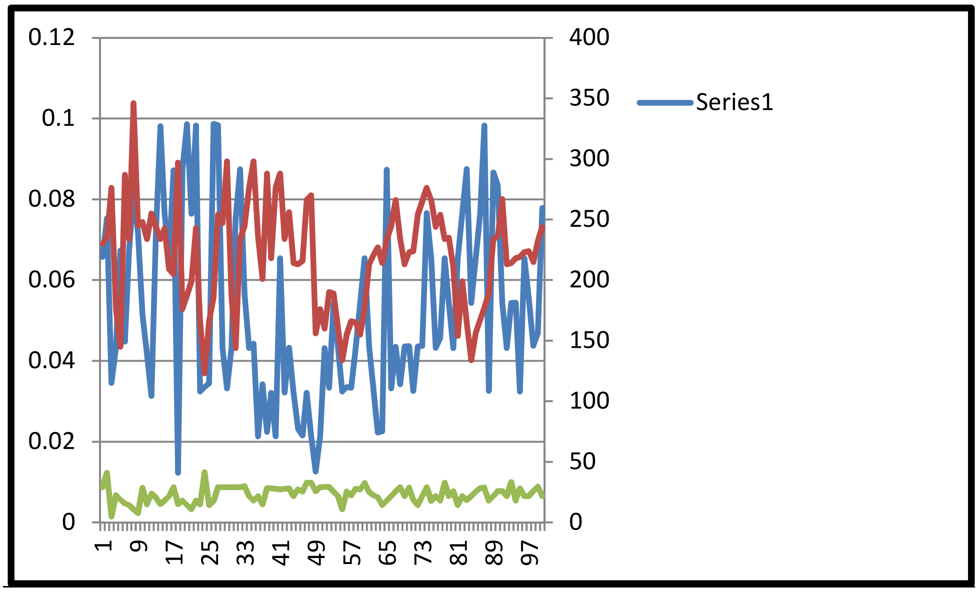


Figure 4.5 b: Data variability graph using linear programming problem (LPP)

<u>A) Optimum parameters for ALUMINIUM UNFLEXED</u>

Let the equation be Y= $e^{a\ +b\ +c}$ + Constant

Ln Y= ax+by+cz + Constant (in log form)

In practical form it becomes

Ln Y (Shelf life)= A (OTR)X+ B(WVTR)Y+ C(PINHOLE)Z+ Constant

Then , through linear regression analysis using SPSS the coefficients were found out

Ln Y = 5.712 (CONSTANT) - 0.272(OTR) - 1.425 (WVTR)- $\left({}^{1}_{4.8}\right)5P$

Now , I considered the above equation as maximising Linear Programming Problem (LPP) i.e at what variable value of OTR, WVTR and Pinhole the self life would be 180

Ln shelf= 5.172- 0.272(OTR)-1.425(WVTR) - $\left({}^{1}_{4.8}\right)5P$ = 180

So , in LPP format the problem takes the shape of the following

By changing OTR, WVTR &PINHOLE

Subject to:

$0.09865 \geq OTR \geq 0.0123$

346 ≥ PINHOLE ≥ 123

0.0125 ≥ WVTR ≥ 0.00147

The max & min values of variables are taken from the corresponding max and min values from the sample.

Now this can be solved as an optimisation problem using the maximum and minimum condition.

0.09865	346	0.0125
0.0123	123	0.00147
OTR TEST cc/m2/day	**Pin holes**	**WVTR TEST**

i.e.optimise the quadratic equation using Solver under two scenario

1) With SHELF LIFE as 180 (common); 2) with SHELF LIFE as 188 (maximum)

The results are as under for Aluminium unflexed

Parameters	SHELF LIFE as 180	SHELF LIFE as 188
OTR	0.06571	0.0123
WVTR	0.00873	0.0125
PINHOLE	199	189

But since Shelf life occurred as 180 days in most cases in the sample, so I will use the data for OTR, WVTR, PINHOLES as 0.06571 , 0.0873, and 199 respectively.

B) Optimum parameters for MPET UNFLEXED

Proceeding in the same direction as above I found the following expected parameters under optimal condition are as follows

The results are as under

Parameters	SHELF LIFE as 180
OTR	0.2283

WVTR	0.21408
PINHOLE	0.02

4.4.3 Optimum barrier combination: Aluminium Vs MPET (flexed)

In order to understand applicability of MPET material as an alternative to aluminum coffee packaging, 52 samples of MPET (flexed) and aluminum (flexed) were tested in the laboratory and following data in respect of OTR, WVTR and Pin Hole can be seen below along with Shelf life data.

Table: 4.10 Laboratory captured data of 52 samples: Aluminum Vs MPET (Flexed)

MPET FLEXED (12 micron)					Aluminium foil Flexed (9 micron)			
Sample No	**OTR Test**	WVTR Test	Pin Holes	Shelf life	**OTR TEST FLEXED**	WVTR FLEX	Shelf Life days	Pin Holes flexed
1	.2460	.2232	.08	150.00	.2199	.1276	180.00	265.00
2	.2345	.2765	.07	164.00	.2310	.1876	180.00	276.00
3	.2199	.2433	.29	168.00	.2432	.1543	178.00	298.00
4	.2134	.2877	.22	179.00	.2143	.2130	180.00	232.00
5	.3765	.3422	.65	142.00	.2321	.2310	175.00	288.00
6	.2766	.1876	.17	156.00	.2134	.2330	167.00	265.00
7	.2432	.1766	.23	158.00	.2343	.2140	180.00	254.00
8	.2234	.2876	.18	168.00	.2430	.1320	180.00	365.00
9	.3455	.2434	.21	145.00	.2450	.1550	180.00	276.00
10	.1765	.2234	.15	170.00	.2443	.3210	180.00	299.00
11	.1654	.3098	.18	170.00	.2090	.1240	180.00	321.00
12	.1876	.3422	.26	172.00	.2132	.1223	150.00	342.00
13	.1876	.3077	.24	160.00	.2320	.2632	180.00	321.00
14	.2234	.2343	.27	150.00	.2322	.2134	180.00	341.00

15	.2344	.2234	.38	150.00	.2132	.2231	180.00	320.00
16	.2222	.2232	.54	150.00	.2321	.3211	180.00	341.00
17	.2987	.2988	.33	132.00	.2343	.2543	180.00	377.00
18	.2998	.3033	.43	129.00	.3211	.3210	180.00	321.00
19	.2987	.2988	.33	132.00	.2343	.2543	180.00	377.00
20	.2998	.3033	.43	129.00	.3211	.3210	180.00	321.00
21	.3244	.3213	.43	120.00	.2320	.2276	157.00	344.00
22	.2343	.2343	.38	126.00	.2130	.2176	165.00	281.00
23	.2234	.2234	.32	134.00	.2432	.2173	180.00	299.00
24	.2235	.2245	.23	150.00	.2577	.2234	180.00	287.00
25	.2873	.4766	.32	150.00	.2198	.2132	176.00	198.00
26	.2344	.2345	.23	150.00	.2132	.2132	180.00	166.00
27	.2344	.2322	.31	150.00	.2155	.2236	180.00	187.00
28	.2144	.2234	.27	150.00	.3321	.4210	178.00	198.00
29	.2455	.2276	.28	147.00	.2189	.3210	180.00	290.00
30	.3566	.3544	.32	124.00	.2143	.2210	180.00	321.00
31	.1765	.1342	.31	176.00	.2321	.1260	180.00	321.00
32	.2344	.2243	.21	160.00	.2343	.2213	180.00	209.00
33	.2188	.2254	.22	160.00	.2440	.2278	180.00	187.00
34	.2176	.2211	.31	160.00	.2567	.2280	156.00	298.00
35	.2187	.2230	.32	173.00	.2346	.2243	177.00	321.00
36	.1677	.2256	.18	174.00	.2311	.2254	180.00	348.00
37	.1655	.2243	.17	176.00	.2322	.2243	180.00	342.00
38	.1876	.2251	.17	177.00	.2430	.3210	178.00	388.00
39	.2122	.2254	.21	180.00	.2320	.2234	180.00	355.00
40	.3765	.2287	.43	123.00	.2210	.2243	180.00	321.00

41	.2299	.2242	.21	150.00	.2298	.2231	180.00	376.00
42	.3765	.2276	.23	132.00	.2265	.2265	180.00	354.00
43	.2234	.2290	.33	150.00	.2433	.2134	180.00	345.00
44	.1988	.2231	.31	168.00	.2544	.2243	177.00	365.00
45	.1980	.2210	.32	168.00	.2655	.3243	180.00	389.00
46	.2114	.2343	.32	160.00	.2322	.2232	180.00	366.00
47	.1765	.2238	.18	155.00	.2432	.2219	180.00	298.00
48	.2231	.2187	.21	150.00	.2431	.2298	180.00	321.00
49	.2455	.2199	.22	144.00	.2653	.2145	188.00	343.00
50	.2234	.2432	.23	150.00	.2765	.2130	180.00	343.00
51	.2234	.2221	.23	150.00	.2163	.2170	180.00	343.00
52	.2254	.2234	.32	152.00	.2236	.2180	180.00	343.00

Table 4.11 : Descriptive Statistics Aluminium Flexed

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
OTR	52	.2111	.1654	.3765	.240040	.0548447	.003
WVTR	52	.3424	.1342	.4766	.249152	.0538187	.003
PINHOLE	52	.58	.07	.65	.2763	.10535	.011
SELFLIFE	52	60.00	120.00	180.00	153.1346	15.93249	253.844
Valid N	52						

Table 4.12 : Descriptive Statistics MPET Flexed

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
OTR1	52	.1231	.2090	.3321	.238528	.0262580	.001

VTR1	52	.2987	.1223	.4210	.228460	.0573311	.003
PINHOLE1	52	38.00	150.00	188.00	177.7308	6.66603	44.436
SELFLIFE1	52	223.00	166.00	389.00	308.5962	55.45472	3075.226
Valid N (listwise)	52						

C) Optimum parameters for MPET FLEXED

Proceeding in the same direction as above I found the following expected parameters under optimal condition are as follows. The results are as under

Parameters	Shelf Life as 180
OTR	0.24598
WVTR	0.23408
PINHOLE	0.02

D) Optimum parameters for Aluminium FLEXED

Proceeding in the same direction as above I found the following expected parameters under optimal condition are as follows.

The results are as under

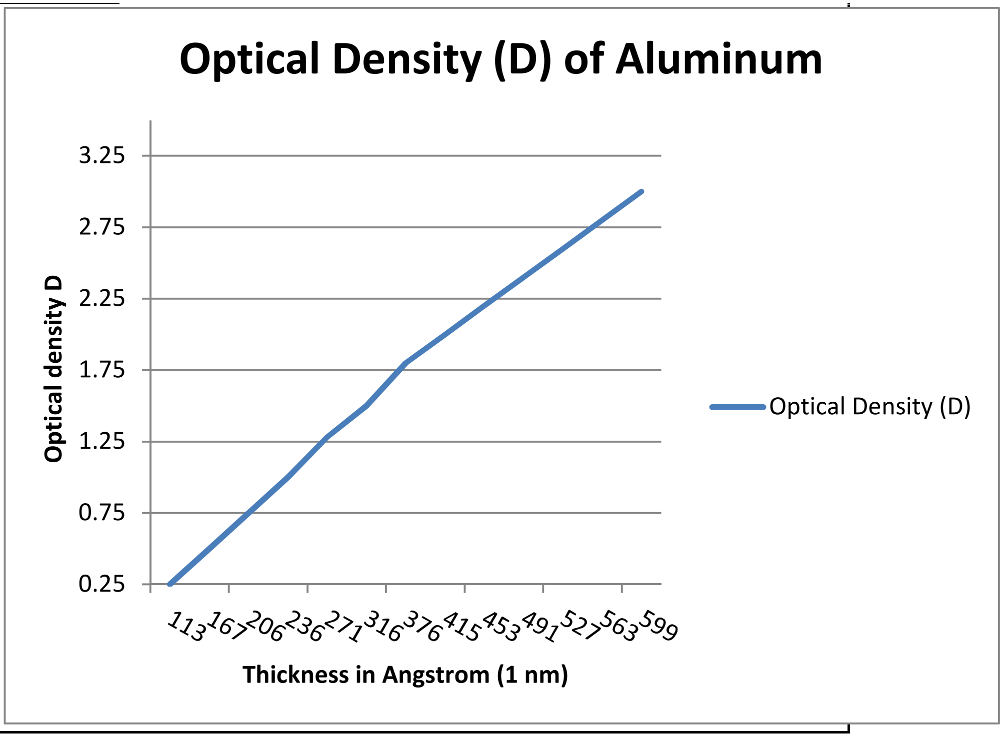
Parameters	Shelf Life as 180
OTR	0.21993
WVTR	0.2910
PINHOLE	200

4.5 Optical density: Aluminium Vs MPET

Optical density is a measure of the light blocking ability of the material and hence very important for coffee packaging. Optical density which is measured with the transmission densitometers. The following table reveals that optical density of Aluminium under different thickness ranges from 113 to 599 Angstrom vary from 0.24 to maximum 3. However, MPET when metalized then it becomes the only the film that has optical density of 2, 2.5, 3, 3.5 under different thickness condition ranging from 113 to 599 Angstrom**.** Since, we are packaging a highly aroma sensitive product and higher the OD higher the barrier light property level. Optical Density (OD) is a convenient way to describe the blocking ability of an optical filter. Higher OD values indicate a higher level of blocking. Here, therefore, it can be seen that MPET has slight better edge over Aluminum foil as packaging material.

Table 4.12b: Optical density of Aluminium

Optical Density (D)	Thickness in Angstrom (1nm)
0.25	113
0.5	167
0.75	206
1	236
1.28	271
1.5	316
1.8	376
2	415
2.2	453
2.4	491
2.6	527
2.8	563
3	599



Source –Applied Films Gmbh

4.6. Shelf Life: Aluminium Vs MPET

Shelf Life is an important consideration for packaging. Whenever, there is a consideration of comparing MPET with Aluminum foil packaging, the later seemed to have advantage in terms shelf life. Therefore, attempt was made to estimate shelf life of ten (10) sample MPET films through laboratory testing. I calculated shelf life of the sample MPET films with the help of Accelerated Age Testing Method known as Arrhenius Reaction Rate Theory.

- Ta = Ambient Temperature = 22°C
- Te = Elevated Temperature created in the testing machine = 35°C
- Q10= Reaction Rate = 2
- AAR (Accelerated Aging Test) = $Q10^{((Te-Ta)/10)}$
- AAR= $2^{13/10}$ = 2.46
- Now calculating the AATD $_{\text{(Accelerated Aging Time Duration)}}$ = Desired Real Time/ AAR
- AATD or Shelf life = 365 days/ 2.46 = 150 days

In the same process , the shelf life of other nine sample were also found out using Accelerated Age Testing Method. The result of this testing experiment is summated in the following table.

Table 4.13: Shelf life using Accelerated Age Testing Method.

Sample No	**Te**	AATD or Shelf life	
		Test result for MPET	Standard for Aluminium
1	35	150	180
2	35	150	180
3	35	150	180
4	35	150	180
5	35	150	180
6	35	150	180
7	35	150	180
8	35	150	180
9	35	150	180
10	35	150	180

4.7 Cost Comparison: Aluminum Vs MPET

Cost of packaging would play an important role in deciding what role MPET will play in Coffee packaging in the future years. A substantial saving in cost would encourage the coffee merchandised also to insist the laminate producers to change packaging material based on MPET laminate. So this study wanted to compare the cost of both the laminate structure, MPET and Aluminum, in order to clearly understand the costing implication in this replacement decision. It can be seen from the table 4.14 and 4.15below that total grammage of MPET structure comes to about 88.8 gm/sqm and that of aluminium to about 115.62 gm/sqm which indicates better usability of MPET structure. The cost of the different constituents of the respective laminates structure were collected from Polyplex limited in order to arrive cost of the concerned structure under consideration. It can be seen from the tables that cost comes out to be 0.17986 USD per square meter for MPET based laminate where as it is about 0.26387 USD for Aluminium based structure. Therefore, it indicates that there will be reduction of Laminate Cost/m^2 by 31.83 percent with use of MPET based structure in coffee packaging in relation to Aluminum based structure.

Table 4.14: MPET film structure and cost

12µPrintedPET+15µExtrudedPE+12µMPET/15 Mic Ext PE +30µPE (Total GSM= 88.8 G/M^2)						
Constituents of the proposed film	**Thickness in micron**	**Density**	**GSM gm/sqm**	**Yield (sq m/kg)**	**Cost in USD/kg**	**Cost in USD/Sq m**
Printed PET	12	1.4	16.8	59.52381	2.15	0.03612
ExtrudedPE	15	0.92	13.8	72.46	1.8	0.02484
MPET	12	1.4	16.8	59.52381	2.15	0.0361
Ext PE	15	1.4	13.8	72.46377	1.8	0.02484
PE	30	0.92	27.6	36.23188	2.1	0.05796
			88.8		10	0.17986

Table 4.15: Aluminum film structure and cost

12µPET+18µPE Extruded+9µAl foil/18 mic Ext PE +45µPE (Total GSM = 115.62 G/M^2)						
Constituents of the proposed film	**Thickness in micron**	**Density g/cm3**	**GSM gm/sqm**	**Yield (sq m/kg)**	**Cost in USD/kg**	**Cost in USD/Sq m**
PET	12	1.4	16.8	59.52381	2.15	0.03612
PE Extruded	18	0.92	16.56	60.38647	1.8	0.02484
Al Foil	9	2.7	24.3	41.15226	3.75	0.09113
Ext PE	18	1.4	16.56	60.38647	1.8	0.02484
PE	45	0.92	41.4	24.15459	2.1	0.08694
			115.62		11.6	0.26387
					11.6	**0.26387**

CHAPTER-5
CONCLUSION AND RECOMMENDATION

5. 1 Conclusion

The main objective of the study was to understand and assess whether Metalized BOPET (Bi-axially oriented polyethylene terephthalate) based structure can replace the Aluminum foil based structure in coffee packaging. The study researched out 13 relevant parameters related to applicability of MPET film based structure which allows its comparison with Aluminum foil based structure. These parameters have been presented below in the tabular form. This table will support us to compare the two types of structure under research and to arrive at the conclusion and recommendation of the study.

It can be seen from the table that the most common Aluminum based structure available and used in the market place consisted of 12µPET+18µPE Extruded+9µAl foil/18µExt PE +45µPE where 9 micron thickness Aluminium foil exist. Similarly, the most common comparable MPET film structure with Aluminum based structure consisted of 12µPrintedPET+15µExtrudedPE+12µMPET/15 Mic Ext PE +30µPE wherein 12 micron thickness of MPET film exist. This study calculated the total Grammage of these two film structure as size of the laminate grammage is directly proportional to cost. The cost calculated out to be 0.17986 USD per square meter for MPET based laminate where as it is about 0.26387 USD for Aluminium based structure. Therefore, reduction of Laminate Cost/m^2 by 31.83 percent with use of MPET based structure in coffee packaging. However, in order to take advantage of reduced cost the produce has to keep in mind that shelf life of MPET is lower by 30 days. To compensate the lower shelf life, the MPET structure is marginally advantageous over Aluminum in terms of Optical density which will reduce aroma loss of coffee over time. The barrier property comparison between the MPET and Aluminium, at this stage, is of utmost importance as coffee packaging material characteristically requires being of high barrier property to check loss of aroma, flavour etc with the passage of time. Amongst about 51 samples, this study found out the optimum combination of three important barrier properties connected with aluminum and MPET based thin film flexible packaging. They are OTR, WVTR and Pinhole when the self life remained constant i.e. 180 days. A close look in to these optimum combinations, as revealed by this study, indicates that under flexed condition, OTR is marginally better for Aluminum and only by 10.59 percent. However, in case of moisture transfer (WVTR), MPET in flexed condition is 24.32 percent better barrier which could be very good for coffee packaging. This is an important finding in the sense that even after passage of certain time MPET film will be able to retain coffee aroma and taste. In addition, number of Pin Hole in MPET, both in flexed and unflexed condition, is much superior than Aluminum foil. Aluminum foil has been used for a longer period of time since past 20 years. The availability of this kind of film is also very high if compared to MPET film. MPET has been newly introduced in the market and is used worldwide now. The various uses of this film for example like use in making food packaging products have made the world see beyond aluminum foil. MPET has taken the world by surprise and has been a strong competitor of Aluminum foil. The MPET film in used in package of various food products taken from milk, butter and now it has taken over coffee packaging also. MPET is a very necessary package in a competitive world of packaging industry. This not only helps in reducing the cost of the package but also keeps the barrier layer intact and performed better than aluminum foil.

Table 5.1: Parameters for comparison between MPET and Aluminum structure

Sl No	Parameters	MPET structure	Aluminum foil structure	Remark
1	Film structure	12µ PrintedPET+15µ ExtrudedPE+**12µMPET**/15 Mic Ext PE +30µ PE	12µ PET+18µ PE Extruded+**9µAl foil**/18µ Ext PE +45µ PE	Randomly selected samples when underwent Delamination test revealed this to most common structure
2	Total GSM	88.8 G/M^2	115.62 G/M^2	Overall laminate GSM possible for the available
3	Cost per m^2 in USD	0.17986	0.26387	MPET structure has reduced cost
4	Expected shelf life	150 days	180 days	Shelf life of Al is 30 days more
5	Maximum Optical density for films (113 to 599 Angstrom)	3.5	3.0	OD is better in MPET hence good for coffee packaging
6	For Optimum structure OTR (Flexed)	0.24598 cc/m^2/day	0.21993 cc/m^2/day	OTR is marginally better for Al (by 10.59 percent)
7	For Optimum structure WVTR (Flexed)	0.23408 g/m^2/day	0.2910 g/m^2/day	WVTR is considerably better for MPET (by 24.32 percent)
7	For Optimum structure Pinholes(Flexed)	0.02	200	Pin holes are much less in MPET hence better for coffee packaging
9	For Optimum structure OTR (un Flexed)	0.22830 cc/m2/day	0.06571 cc/m^2/d	OTR is better for Al (about 71.22 percent)
10	For Optimum structure WVTR (un Flexed)	0.21402 g/m^2/day	0.00873 g/m^2/day	WVTR is better for Al (about 95.92 percent)
11	For Optimum structure Pinholes(un Flexed)	0.02	199	Pinholes are less in MPET
12	Family consumption of coffee /month is highly correlated with factors like	1) Taste and flavor of coffee, 2) Buyers awareness of different coffee aroma, 3) Heat resistant characteristics of packaging material and 4) Moisture proof characteristics of packaging material.		Clearly shows buyers will be happy if Taste and flavor of coffee are intact under packaging condition
13	Family consumption of coffee /month is not correlated with factors like	1) Price of coffee, 2) Packaging material used by a company and 3) Aluminum as material used for coffee packaging .		Clearly shows that if there is changing of packaging material , there will be no effect on consumption

5.2 Recommendation

MPET, therefore, decelerate the degradation of the contents. It can also be seen from the table 5.1 that under unflexed condition (fresh) the Aluminum foil laminate has substantial better barrier property (OTR better by about 71.22 percent and WVTR is better by about 95.92 percent).

But as we have found out in this study that with the passage of time these barrier property reduced drastically and this study shows that in the flexed condition MPET film recorded comparatively better barrier property.

In addition, this study shows also that coffee consumers while buying coffee prefer that taste and flavor of coffee will remain intact under packaging condition.

Also buying of coffee is not at all dependent on material used for packaging. This clearly indicates that if MPET laminates structure is used for coffee packaging then it will enjoy two clear advantages; one , reduction of Cost/m^2 by 31.83 percent and two, aroma and taste of coffee will not suffer from deterioration even after elapse of time.

Hence, this study find wisdom in replacing usual **Aluminum foil structure (**12µPET+18µPE Extruded+**9µAl foil**+18µ Ext PE +45µPE) with **MPET structure (**12µPrintedPET+15µExtrudedPE+**12µMPET**+15 Mic Ext PE +30µPE)

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- Polyplex library , Bowin , Thailand

About Polyplex limited where the study carried out

Polyplex Corporation Ltd. (Polyplex) is among the world's largest manufacturers of thin PET film. The company run integrated manufacturing & distribution operations in six countries viz. India, Thailand, Turkey, U.S.A., China & Netherlands. It has global presence, supplying to about 1571 customers in 76 countries across Europe, Americas, the Indian sub-continent, Far East, Asia Pacific and the Middle East. Its polyester capabilities include both thin and thick PET film in a wide range of thickness and surface properties covering a spectrum of applications, diversified products includes BOPP film and CPP film produced in new state-of-the-art plants. Integrated downstream capabilities of Metallizing, Silicone Coating, Offline Chemical Coating and Extrusion Coating deliver further value-added products.

APPENDIX

Consumer Survey Questionnaire

Instructions

Answer questions as they relate to you. For most answers, check the box (es) most applicable to you or fill in the blanks.

About You

1. Your Age

(Select only one.)

1:17 or less
2:18-25
3: 26-35
4: 36-45

2. Your Gender

1.Male
2.Female

3. Do you take coffee every day?

(Select those apply.)

1. Yes
2. No
3. Sometimes

General Question

4. If yes, how much coffee approximately your family consume in a month

(Select only one.)

1. Below 500 gm
2. 500- 1000 gm
3. 1000-1500 gm
4. 1500-2000 gm
5. More than 2000gm

☐Doesn't matter

Consumption preference Related

5. Is your buying behaviors influenced by price ?

1. Not at all
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

6. While buying and selecting coffee brand how much you are influenced by the taste and flavor of coffee?

1. To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

7. How much you are aware of different coffee aroma like Brazilian coffee, Cappuccino, Vietnam coffee etc ?

1. To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

8. How much you pay attention to the coffee packaging material ?

1.To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

9. How much you are influence if aluminum material is used as coffee packaging?

1.To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

9. Do you consider that packaging material should be moisture proof?

1.To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause

10. Do you think that coffee packaging material should be heat resistant one ?

1.To a least extent
2. To some extent only
3. Moderately
4. To a great extent
5. This is the only cause