

**REFUSE-DERIVED PLASTIC FROM WASTE
EXPANDED POLYSTYRENE AND USED
DEEP-FRIED OIL**

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UNIVERSITI MALAYSIA PERLIS

2009



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EXPANDED POLYSTYRENE AND USED
DEEP-FRIED OIL**

by

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A thesis submitted
In fulfillment of the requirements for the degree of
Master of Science (Polymer Engineering)

**School of Materials Engineering
UNIVERSITI MALAYSIA PERLIS**

2009

ACKNOWLEDGEMENT

In the name of Allah the Almighty, I am very grateful for the courage and blessing, He gives to me in completing this final project and partial fulfillment of the requirements for the award of Master (Science) in Polymer Engineering.

A bouquet of thanks and gratitude to my beloved supervisors, Prof. San Myint for her invaluable guidance, assistance, suggestions, encouragements and patience, the course of carrying out this study.

Gratitude is also extended to all the polymer lecturers for their kindness and unselfish effort and cooperation to bring this thesis to reality.

A special thanks also goes to my beloved mum, Zubiah Binti Mohd Nor for her support and understanding during this study.

Finally, thanks a lot to all my colleagues and PLV who always gave valuable assistance and supports during this study. Without your help and encouragement, this report will never materialize. I will never forget the invaluable knowledge and experiences that all of you gave to me. Thank you again.

APPROVAL AND DECLARATION SHEET

This project report entitled “Refuse-Derived Plastic From Waste Expanded Polystyrene and Used Deep-Fried Oil” was prepared and submitted by Noor Aishatun binti Majid (Matrix No: 0831620292) and has been found satisfactory in term of scope, quality and presentation as partial fulfillment of the requirement for the Master of Science Polymer Engineering, School of Materials Engineering in Universiti Malaysia Perlis (UniMAP).

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October 2009

PENGHASILAN PLASTIK BAHAN TERBUANG (SAMPAH) DARIPADA BUSA POLISTERINA (EPS) TERBUANG DAN MINYAK MASAK TERPAKAI

ABSTRAK

Plastik berasaskan bahan terbuang (sampah) melalui teknik percampuran larutan antara busa polisterina (EPS) terbuang dan minyak masak terpakai telah dihasilkan. Melalui penyelidikan ini, semua formulasi berkaitan telah dipilih berdasarkan ciri-ciri kelikatan dan sifat fizikal plastik. Metil etil keton perosid (MEKPO) sebagai pemula tindakbalas dan cobalt-naphthenate bertindak sebagai penggalak telah ditambah berdasarkan kuantiti yang bersesuaian. Penyiasatan dalam ujian keterlarutan bagi EPS dalam pelarut MEK menunjukkan bahawa 10 gm MEK dan 5 gm busa polisterina (EPS) terbuang adalah campuran yang berkesan dalam penghasilan formulasi terbaik dalam penghasilan plastik berasaskan bahan terbuang (sampah). Eksperimen yang telah dilakukan berdasarkan penyediaan plastik berasaskan bahan terbuang (sampah) dengan kuantiti yang pelbagai bagi minyak masak terpakai di dalam busa polisterina (EPS) bersama-sama pelarut MEK menunjukkan 15 berat % minyak masak terpakai (UDFO) boleh bertindakbalas dengan busa polisterina (EPS) terbuang dan nilai tertinggi dicatatkan bagi kekuatan berkaitan dengan ketegangan dan kekuatan flexural iaitu 3.579 MPa and 6.520 MPa. Morfologi dan ciri pelaksanaan bagi antara busa polisterina (EPS) terbuang yang diisi dengan 15 berat % minyak masak terpakai dan busa polisterina (EPS) terbuang yang diisi dengan 15 berat % minyak baru (FO) telah dipastikan dan dibandingkan. Semua ujian menunjukkan plastik berasaskan bahan terbuang (sampah) yang telah disediakan mempunyai beberapa kelebihan seperti cemerlang dalam kekuatan berkaitan dengan ketegangan, pemanjangan semasa putus, elastik modulus dan kekuatan flexural jika dibandingkan busa polisterina (EPS) terbuang yang diisi dengan 15 berat % minyak baru (FO).

REFUSE-DERIVED PLASTIC FROM WASTE EXPANDED POLYSTYRENE AND USED DEEP-FRIED OIL

ABSTRACT

A refuse-derived plastic was produced by mixing waste Expanded Polystyrene (EPS) in solution with used deep-fried oil (UDFO). A measured amount of methyl ethyl ketone peroxide (MEKPO) was added as a reaction initiator and cobalt-naphthenate as a promoter. Investigation of solubility test of EPS in MEK solvent indicates that 5 g waste and EPS 10 g MEK were found to be an effective mixture to make the best formulation in making refuse-derived plastic. Experiments on preparation of refuse-derived plastics with different amount of used deep-fried oil and Polystyrene in MEK solution indicates that 15 wt. % of UDFO cooperated well with waste EPS and resulted the highest tensile strength and maximum stress (flexural strength) 3.579 MPa and 6.520 MPa. The morphology and performance characteristic of the prepared waste expanded polystyrene (EPS) based plastic filled with 15 wt. % used deep-fried oil (UDFO) and 15 wt. % fresh oil (FO) were determined and compared. The tests showed that the prepared refuse-derived plastic has some advantages such as excellent tensile strength, elongation at break, modulus of elasticity and flexural strength compared with waste expanded polystyrene (EPS) based plastic filled with 15 wt. % with fresh oil (FO).

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LIST OF SYMBOLS, ABBREVIATIONS OR NOMENCLATURE

EPS	Expanded polystyrene foam
PS	Polystyrene
MEK	Methyl ethyl ketone
MEKPO	Methyl ethyl ketone peroxide
g	gram.
ml	Milliliter.
μ	Micro.
rpm	Rotation per minute.
VOC	Volatile Organic Compound.
pH	Potential hydrogen (a measure of the acidity or alkalinity of a solution).
IR	Infra Red.
°C	Degree Celsius.
%	Percent.
CIWMB	California Integrated Waste Management Board.
U.S	United State.
M	Million.
bn	Billion.
N.	Nitrogen.
C	Carbon.
O	Oxygen.
°F	Fahrenheit.
ppm	Part per million.
CH	Carbon-hydrogen chemical bond.
CH ₂	Methylene (functional group).
C ₈ H ₈	Styrene.
C ₆ H ₆	Benzene.
kg	Kilogram.

cm ³	Cubic centimeter.
(M)	Malaysia.
μm	Micrometer.
mm	Millimeter.
cm	Centimeter.
No.	Number.
in.	Inch.
cP	Centripous
MPa	Mega Pascal

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CHAPTER 1

INTRODUCTION

1.1 Background of waste expanded polystyrene (EPS)

The nondurable goods represent as the largest category of polystyrene (PS) in U.S., 63 percent, with plastic plates and cups alone representing 39 percent. While, the durable goods account for about 27 percent, with packaging amounting to about 10 percent. A substantial amount of PS is used in the building and construction industry, mostly for insulation materials, but these wastes are not considered part of the U.S. MSW stream.

The EPA reports recovery of about 10 thousand tons of PS from durable goods in 1998, a recycling rate of only 1.7 percent. No significant recovery of nondurable goods was reported. Another 10 thousand tons were recovered from the packaging category, for a 4.8 percent recycling rate, resulting in an overall recycling rate for polystyrene of only 0.9 percent. There is very little recycling of food-service PS in the U.S.A.

In 1989, the National Polystyrene Recycling Company (NPRC) was formed by several PS producers, with a goal of achieving a 25 percent recycling rate for food-service PS by 1995. It focused on institutional generators of such wastes, primarily schools, and other cafeterias. However, the operation was plagued by high levels of contamination with food wastes and was unable to operate profitably (Grassie & Kerr, 2001).

Recycling rates and amounts for PS food-service items, including packaging, declined after an initial period of growth. In 1999, NPRC and its remaining two recycling facilities were sold to Elm Packaging Company and its name changed to Polystyrene Recycling Company of America. By late 2000, the company evidently stopped accepting PS food packaging for recycling (Cameron, 2003).

Nearly all recycling of PS from packaging in the U.S.A. now comes from recycling of foam cushioning materials. Such recycling has been much more successful than recycling of food-service PS. Recycling rates have, for the most part, been at the 9 to 10 percent level for the last several years. The American Plastics Council reported a recycling rate for EPS packaging of 9.6 percent in 1999, up from 9.5 percent in 1998. The amount recycled increased by 1 million pounds, reaching 20.2 million pounds in 1999. The Alliance of Foam Packaging Recyclers reports availability of more than 200 collection sites in the U.S.A. and Canada for post-consumer EPS protective packaging.

The organization web site includes information for consumers about collection locations available in their area. Much of the collected material is used in manufacture of new EPS packaging, often in a blend with virgin resin. Cushioning materials made with 100 percent recycled PS are also available. In addition to recycling, there is considerable reuse of expanded polystyrene loose fill. The Plastic Loose Fill Council operates a toll-free "Peanut Hotline" to provide information to consumers about where to take EPS loose fill for reuse. The organization reports that over 30 percent of all EPS loose fill is reused, and more than 1,500 collection sites for the material are available in the U.S.A (Freedman S, 2002).

In addition, post-consumer recycled-content loose fill is widely available. One of the leaders in EPS recycling in the U.S.A. is FR International, which recycled 10.9 million pounds of expanded polystyrene in 2000, an increase of nearly 2 million pounds over 1999. The company, which began PS recycling in 1990, now has five recycling operations in the U.S.A. and also has a UK subsidiary that recycled over 2.5 million pounds of polystyrene in 2000 (Scott, 2005).

One of the problems in recycling EPS is the very low bulk density of the material, which makes shipping it over long distances uneconomical. International Foam Solutions, Inc. (IFS), of Delray, FL, has developed a process that dissolves EPS in a citrus-based solvent, producing a gel and eliminating 90 percent of the volume. The "Polygel" is stored in drums and shipped to IFS for processing. An IF further dilutes the gel, filters out contaminants, and produces new PS products. Contaminant levels are reportedly reduced to less than 1 ppm. In addition to cushioning materials, the system can successfully recycle PS from food service use. The company sells or leases its "IFS Solution Machine" to customers and has several food service operations as customers. Sony Corporation Research Center, in Yokohama, Japan, has also developed a solvent-based PS recycling system that uses d-limonene (Sato, 2000).

Another company attempting to use food-service PS is Rastra Technologies, Inc. It manufactures wall panels made of recycled PS and cement. In 1999, it participated in a pilot with a Florida school district to recycle used PS foam lunch trays. In the early 1990s, five McDonalds restaurants were constructed using the company's insulated concrete form (ICF) panels containing recycled PS hamburger boxes.

Kodak operates a recycling program for PS in disposable camera bodies, and also recycles film containers. Recovered camera bodies are ground, mixed with virgin resin, and used in the production of new disposable cameras. The PS internal frame and chassis of the cameras are recovered intact and reused in new cameras. The cameras are collected from photofinishers, who are reimbursed for the cameras they return. The company's program is active in over 20 countries, and achieves a recycling return rate of over 70 percent in the U.S.A. and approximately 60 percent worldwide. Kodak reports that by weight, an average of 86 percent of Kodak one-time-use cameras are recycled or reused (Sato, 2000).

While there appears to be no current commercial use of the system, some years ago, the Toyo Dynam company, in Japan, developed a prototype system for feedstock recycling of PS in which foam PS was ground and sprayed with styrene monomer to dissolve it and separate it from contaminants. The solution was then cracked and vaporized in a heated reflux vessel. Some PS is also recycled from appliances. In Japan, one of the goals of the Japan Expanded Polystyrene Recycling Association (JEPSRA) is to increase recycling of expanded PS. The organization reports that 53.6 percent of EPS in Japan is used in containers, 32.5 percent in transport packaging, and 13.9 percent in building materials and civil engineering applications (Murakata, 2006).

With a network of more than 1000 recycling sites, Japan achieved a 35 percent recycling rate for EPS in 2000. JEPSRA has a goal of a 40 percent rate by 2005. Korea reports a recycling rate of 48.8 percent for EPS in 1999, excluding building insulation and food containers, for a total of 24,371 tonnes (Ohama, 2004).

The Canadian Polystyrene Recycling Association (CPRA) was reported that more than a million households in Ontario and Manitoba can recycle polystyrene at curbside. The CPRA recycling plant in Mississauga, Ontario, has a capacity of up to 3,500 tonnes of PS a year. It accepts both food service PS and cushioning materials. Europe also has some recycling of PS food service items as well as cushioning. In the UK, the Expanded Polystyrene Packaging Group (EPS) reports that 4,500 tonnes of expanded polystyrene packaging were recycled in 2000, for a recycling rate of nearly 15 percent. This was a significant increase from the 3,000 tonnes recycled in 1999, a rate of 10 percent. The growth was attributed to interest in wood replacement products and an increase in the price for virgin PS resin as well as efforts by the group to develop recycling processes and raise awareness about the potential benefits of EPS recycling (Freedman, 2004).

The amount of waste of polystyrene (PS) foams is increasing in last year's due to the increase of their use in isolation, protecting, storing and serving many different food products. Continuous accumulation of waste plastics leads to serious problems all over the world (Seung-Soo & Seungdo, 2004).

Recycling of this waste has recently received significant attention all over the world due to the changes in both regulatory and environmental issues. Increasing landfill costs and decreasing landfill space are forcing consideration of alternative options for the disposal of polystyrene materials. The two main alternatives for treating polymer wastes are energy recycling, where wastes are incinerated, and mechanical recycling (Garforth et al., 2004). Environmental argumentations such as toxic emissions are building up a public resistance against incineration process (British Plastic Federation).

Mechanical recycling (the conversion of “scrap” polymer into new products) is a popular recovery path for manufacturers and is carried out on single-polymer waste streams. Anyway, the market for recycled products can only be found if the quality is close to that of the original. Unfortunately the process of recovery of these wastes are often more expensive than virgin plastic (Brandrup, 1996; Lee, 1995).

On the other hand, these recycling processes have other economic problems related to the transportation cost. The low density of polystyrene waste and therefore, the transport of the big volume residues make economically unfeasible these processes. Considering this fact, other processing schemes should be explored in order to reduce the cost of the two recycling processes mentioned before. It could be accomplished by dissolution with suitable solvents in order to get a volume reduction of more than 100 times (without degradation of polymer chains), since, if dissolution is developed in the source of residue production the transportation is more efficient than in the conventional recycling system.

Thus, PS foams dissolution behaviour in different solvents plays an important role in polystyrene recycling, because it is an attractive alternative to incineration and mechanical recycling since is the cheapest and one of the most efficient ways for PS foam recycling. It is well known that some aromatic compounds are good solvents of PS foams (Karaduman et al., 2002). Certain foods items have been shown to be incompatible with the expanded polystyrene used for the manufacture of food containers, since, the dissolution of polystyrene by certain essential oils are produced (Monte & Landau-West, 1982).

The treatment of PS with d-limonene has been reported as an attractive alternative for PS solubilization (Nocuchi et al., 1998). However, the earlier works do not show the solubility values or the chain degradation during the dissolution process. García et al. (2009) have been done the development of a suitable process for the recycling of extruded polystyrene in two steps. First, polystyrene dissolved with suitable solvents in the same place where the residue is produced. Second, a solvent elimination step by vacuum distillation in a recycling plant.

Accordingly, this paper evaluated the solubility of polystyrene in several solvents. The degree of polymer chain degradation that the solubilization process produces, as well as the degradation produced during the solvent elimination step has been analyzed in order to select the best solvent.

1.2 Process development of Used deep-fried oil (UDFO)

The latest development on the recovered frying oil is more on the production of biodiesel. Biodiesel is a nonpetroleum-based fuel defined as fatty acid methyl or ethyl esters derived from vegetable oils or animal fats and it is used in diesel engines and heating systems. Thus, this fuel could be regarded as mineral diesel substitute with the advantage of reducing greenhouse emissions because it is a renewable resource. However, the high cost of biodiesel is the major obstacle for its commercialization; the biodiesel produced from vegetable oil or animal fat is usually more expensive than petroleum-based diesel fuel from 10 to 50% (Felizardo et al., 2006).

Moreover, during 2007, the prices of virgin vegetable oils have nearly doubled in relation to the early 2000s (Aladedunye, 2008). This is of great concern to biodiesel producers, since the cost of feedstock comprises approximately 70–95% of total operating costs at a biodiesel plant. Compared to neat vegetable oils, the cost of waste vegetable oils is anywhere from 60% less to free, depending on the source and availability (Felizardo, 2004).

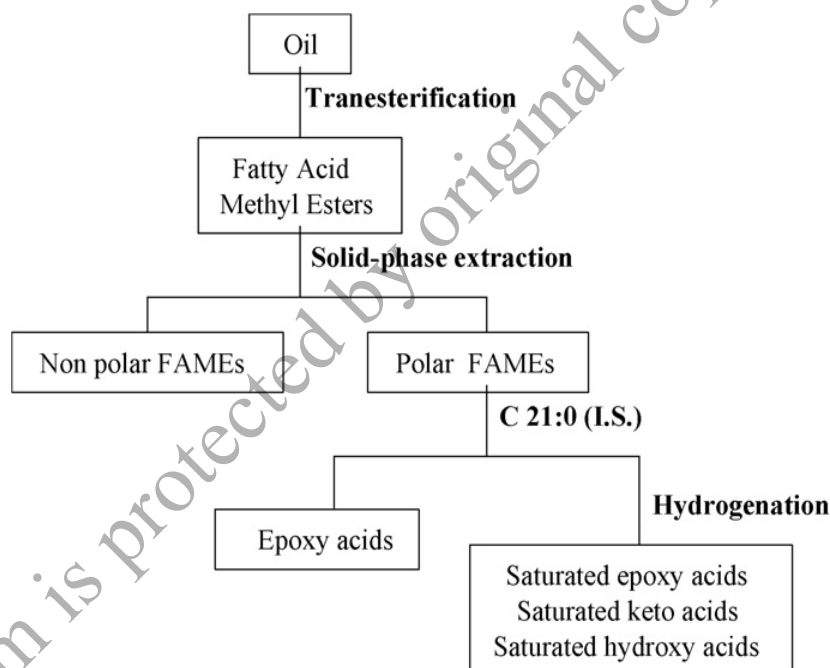


Figure 1.1: Analytical scheme for the analysis of oxidized fatty acids

Besides, Marmesat (2008) found that the levels of epoxy acids, keto acids and hydroxy acids formed in oils during processes that involve high temperatures, such as the frying process as shown in Figure 1.1. Identification of compounds was carried out in thermoxidizedmethyl oleate and methyl linoleate because they are representative of the two principal fatty acyl groups undergoing degradation in frying oils. It proved that recovered frying oil which experience high temperatures will be able to form the beneficial monomers in polymer technology.