FT-IR Analysis of Recycled Polystyrene for Food Packaging

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Summary: Recycled polystyrene is used to form moulds in various forms used as food containers. In this paper, we are reporting on the suitability of recycled polystyrene and virgin polystyrene used for manufacturing food containers in Pakistan. These polystyrene samples were kept in contact with the vegetable oil at different temperatures ranging from 15–100 °C. These samples were analyzed by FT-IR and viscometer. The study demonstrates that recycled polystyrene undergoes some thermal degradation during recycling and the food containers prepared from these materials should not be used for storage of oily food at high temperature.

Introduction

Plastics usage is increasing rapidly in the today's world, from household to space products, and consequently a large amount of plastic waste is being generated. The plastic products degrade very slowly and therefore, plastic waste has become a source of growing public concern. Considerable commercial and environmental benefits can be achieved by recycling the plastic waste [1].

The recycled material always contains traces of degraded material and contaminants and is usually of inferior quantity to that of the virgin material. Polymer degraded during service can act as a prodegradant when recycled. The chemical degradation of polymers occurs through chain reactions that involve products of reaction such as free radicals and hydroperoxides [2-9]. Thus, if the recycled material contains such products of reaction they may be able to seed degradation in the recycled product.

Degradation usually involves chain scission, though crosslinking may also occur. With polystyrene both scission and crosslinking are present. The rates of formation of both scissions and crosslinks depend on the amount of oxygen available [10-11]. Thus, the amount and nature of the degraded polymer will depend on the application of the original product as well as the temperature and other environmental effects during service. Thermal, physical and rheological properties of the recycled products have been investigated [12-14] and reviewed for their application in food packaging [15]. Recycled plastics can be used in food content application if strict compliance to the regulation is attained [16].

In this study, we have analyzed virgin and recycled polystyrene used for manufacturing food containers. These food containers are also used for packing oily food. The vegetable oil in contact with the polystyrene at different temperatures was analyzed. Our concern was to see whether the recycled food packaging products could be used for oily hot food without leading to any contamination.

Results and Discussion

Table- 1 summarizes the viscosity average molecular weight ($\bar{M}_v$) of a virgin and two recycled polystyrene samples. Table 1 shows that ($\bar{M}_v$) of the recycled material is less than the virgin polystyrene sample (A). This reduction in ($\bar{M}_v$) of recycled material is attributed to the recycling process in which long chain polystyrene thermal degradation can occur [1].

Table- 1: Viscosity average molar mass of three polystyrene samples: virgin (A), recycled (B), recycled (C).

Polystyrene Samples	Molar Mass ($\bar{M}_v$) x 10^{-5}
virgin (A)	1.42
recycled (B)	1.04
recycled (C)	1.09

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The FT-IR spectrum of polystyrene (sample A) is shown in Fig. 1. The spectrum shows C-H stretching of benzene (peaks at 3061 and 3027 cm^{-1}) and the C-H stretching in $-CH_2-$ at 2851 cm^{-1}. The FT-IR spectrums (not shown) of samples B and C show the same spectral features and completely overlap with the sample A spectrum.

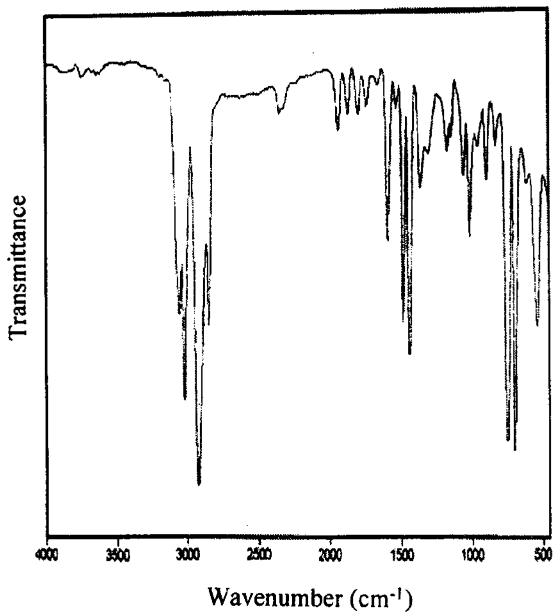

Fig. 1. FT-IR spectra of virgin polystyrene (A).

Fig. 2 shows the FT-IR spectrum of vegetable oil used in the study. The spectrum shows a C-H stretching in $-CH_2-$ at 3007 cm^{-1}, an ester C = O stretching at 1746 cm^{-1}, an ester C-O stretching at 1235 cm^{-1}, and C-H deformation at 1459 and 1371 cm^{-1}

In order to determine the suitability of polystyrene for oily food packing, virgin and recycled polystyrene films were kept in oil for 24 hours at 15 °C (refrigeration temperature) before taking them out and recording the FT-IR spectrum. Figure 3 shows the spectrum of these oil samples containing virgin (Fig. 3a) and recycled polystyrene (Figs. 3b and 3c). All these spectra are identical and show the same spectral features as that of the pure vegetable oil (Fig. 2). No peaks were observed that correspond to polystyrene by-products. This shows that virgin and recycled polystyrene don't contaminate the oil and therefore can be used for storing oily food at refrigeration.

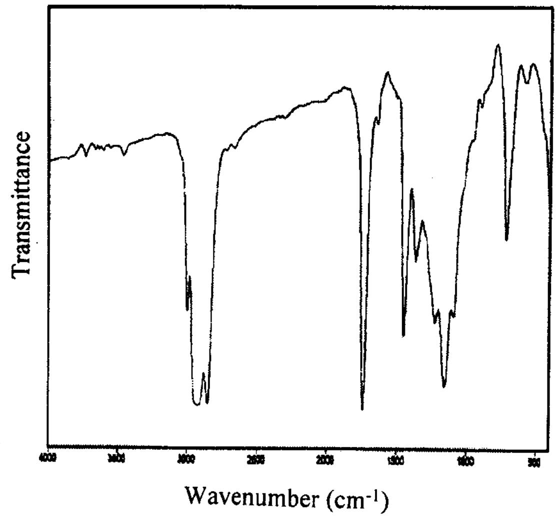

Fig. 2. FT-IR spectra of vegetable oil.

The effect of polystyrene on the quality of vegetable oil at 60 °C is shown in Fig. 4. With virgin polystyrene, the FT-IR spectra of oil (Figure 4a) show only the spectral features of pure vegetable oil (Fig. 2). This means that at a high temperature contact between virgin polystyrene and oil does not affect the quality of the oil and therefore no thermal degradation products of polystyrene leach out into oil. The FT-IR spectrum of oil containing recycled polystyrene samples B and C (Figs. 4b and 4c) on the other hand clearly shows the presence of spectral features of polystyrene (C-H stretching of benzene at 3061 and 3027 cm^{-1}, Fig. 1). Based on the presence of benzene peaks in the FT-IR spectrum of the vegetable oil, it is reasonable to conclude that the recycled polystyrene material has undergone some thermal degradation during recycling process and the degraded products (probably monomers and oligomers) have leached out of the film into the vegetable oil at high temperature. The FT-IR spectra (Fig. 5) of oil at 100 °C studies have also shown similar behaviour as in Fig. 4.

The effect of temperature on the contamination of oil by virgin and recycled polystyrene is summarized in Table- 2. It is clear that in recycled polystyrene, small molecules degradation products form during recycling process and at higher temperature there is accelerated diffusion of degraded products into the oil phase.

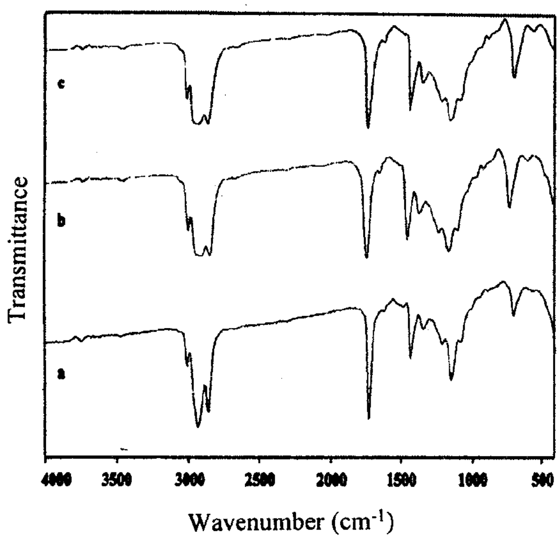

Fig. 3. FT-IR spectra of vegetable oil in which polystyrene films were kept for 24 hrs at refrigeration temperature (15 °C): (a) virgin polystyrene (A), (b) recycled polystyrene (B), (c) recycled polystyrene (C).

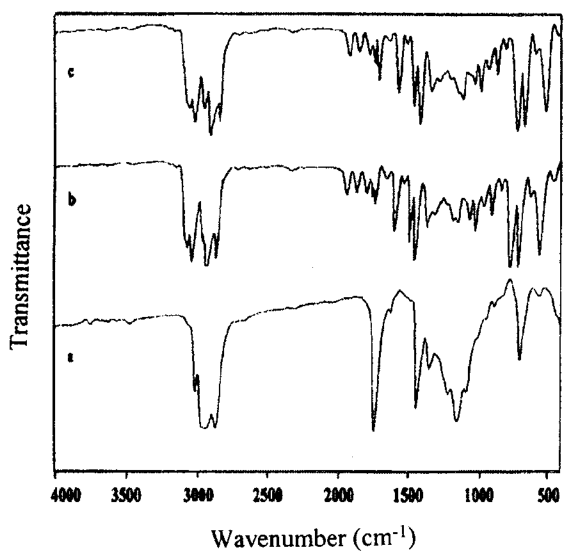

Fig. 4. FT-IR spectra of vegetable oil in which polystyrene films were kept for 30 min at 60 °C: (a) virgin polystyrene (A), (b) recycled polystyrene (B), (c) recycled polystyrene (C).

In this work, we have shown that simple and fast FT-IR measurements can be used for determining the suitability of recycled polystyrene material for food packaging containers. The FT-IR analysis has unequivocally demonstrated that polystyrene degraded material during recycling process can leach out in the vegetable oil at high temperatures (60 °C and 100 °C) but at refrigeration temperature (15 °C) no such leaching of material occurs. It is reasonable to suggest that recycled polystyrene should be properly analyzed before its suitability for oily food storage at high temperature.

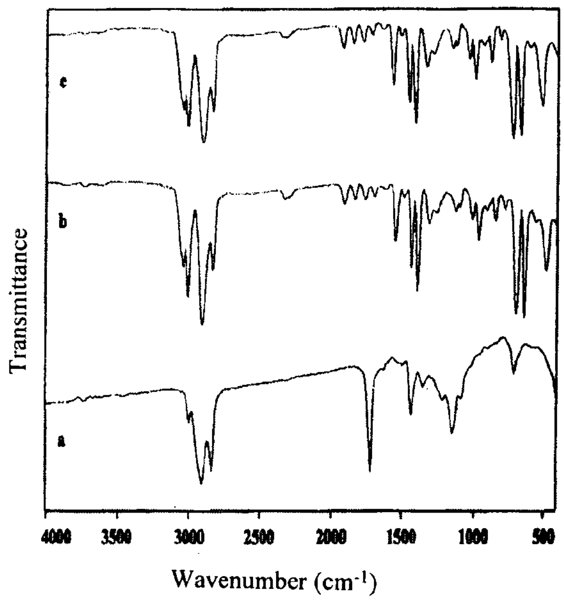

Fig. 5. FT-IR spectra of vegetable oil in which polystyrene films were kept for 30 min at 100 °C: (a) virgin polystyrene (A), (b) recycled polystyrene (B), (c) recycled polystyrene (C).

Table- 2: Temperature dependent contamination of vegetable oil by polystyrene: virgin (A), recycled (B), recycled (C). (+) contamination, (-) no contamination.

Polystyrene Samples	Temperature (°C)		
	15	60	100
virgin (A)	-	-	-
recycled (B)	-	+	+
recycled (C)	-	+	+

Experimental

Virgin Polystyrene (sample A) and recycled polystyrene were purchased from the local market. The recycled polystyrene exists in two grades; one is white (sample B) and the other is pinkish in colour (sample C). All of these polystyrenes are used for moulding food containers. The cooking oil used was commercially available vegetable oil, Dalda brand, Pakistan. These materials were used without any treatment. All chemicals were of analytical grade and were used as received.

Polystyrene films were prepared from 2 % polymer solution in chloroform. The films were dried in vacuum oven at 60 °C for 24 hours. These films were used for the thermal and polymer/ oil contact experiments.

Intrinsic viscosity [η] of all polystyrene samples was determined in toluene solvent at 30 ± 0.01 °C. The viscosity average molecular weight ($\bar{M}_v$) was determined from $[\eta] = K(\bar{M}_v)^a$, using the Mark-Houwink-Sakurada constants K = 0.011 mL/ g and a = 0.72 for istactic and atactic polystyrenes [17].

Fourier Transform Infrared (FT-IR) transmission spectra were recorded using a MIDAC M Series FT-IR spectrometer with a resolution of 4 and 2 cm^{-1} in the infrared range 4000-500 cm^{-1}. For polymer analysis, thin films were prepared from 2 % (w/ v) chloroform solution cast on KBr disks. The films were completely dried by keeping them in vacuum oven at 40 °C for ~3 hours. For oil samples, a drop of oil was squeezed between the flat KBr plates (that makes a thin film of 0.1-0.3 mm) and spectra were recorded. In polystyrene/vegetable oil contact experiments, four dried polystyrene film (thickness = 0.56 mm, Diameter = 70 mm) was dipped in 100 ml of vegetable oil. The experiment was carried out at 15 °C (refrigeration temperature), 60 °C and 100 °C with different dip time. At the refrigeration temperature, the film was kept in the oil for 24 hours whereas at 60 °C and 100 °C the film was kept for 30 minutes. After the specified times the films were taken out of the oil and FT-IR spectra of oil were recorded. All the spectra of polystyrene film and vegetable oil were recorded with 64 scans and at 25 °C.

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References

1. J. R. White, A. J. Turnbull, *Mater. Sci.* **37**, 109 (2002).
2. A. Davis, D. Sims, *Weathering of Polymers, Appl. Sci. Publs., London*, (1983).
3. J. R. White, A. Turnbull, *J. Mater. Sci.* **29**, 584 (1994).
4. J. F. Rabek, *Photodegradation of Polymers (Physical Characteristics and Applications,* Springer, Berlin, (1996).
5. N. S. Allen, M. Edge, *Fundamentals of Polymer Degradation and Stabilisation,* Elsevier Applied Sci., London, (1992).
6. J. R. White, N. Y. Rapoport, *Polymer Trends.* **2**, 197 (1994).
7. N. Grassie, Scott, G. *Polymer Degradation and Stabilisation,* Cambridge University Press, Cambridge, (1988).
8. J. F. Rabek, *Mechanisms of Photophysical Processes and Photochemical Reactions in Polymers (Theory and Applications)*, Wiley, Chichester, (1987).
9. G. Scott, *Polym. Degrad. Stab.* **10**, 97 (1985).
10. A. V. Shyichuk, D. Y. Stavychna, J. R. White, *Polym. Degrad. Stab.* **72**, 279 (2001).
11. A. V. Shyichuk, J. R. White, *J. Appl. Polym. Sci.* **77**, 3015 (2000).
12. D. A. Hoffaman, Annu. Tech. Conf. Soc, Plastic Engineering 52nd, **1**, 880 (1994).
13. D. Braum, Jr, *Kautsch. Gummi. Kunstst*, **47**, 196 (1994).
14. H. Dijidjelli, D. Benachour, *Macromol. Symp.* **127**, 181 (1998).
15. M. R. Milana, *Food Addit. Contam.*, **15**, 355 (1998).
16. G. W. Arndt. Jr, Natl. Food. Process. Assoc. USA. 5th, 59 (1991).
17. Kurata M.; Tsunashima, Y. *Polymer Handbook*, 3rd ed., New York: Wiley, (1989).