Biodegradation of 2-HEMA-g-Na-PCMS a polymeric matrix synthesized from natural modified carbohydrates

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2-hydroxyethyl methacrylate (2-HEMA) was graft copolymerized with sodium salt of partially carboxymethylated starch (Na-PCMS). Thus, prepared graft copolymer (2-HEMA-g-Na-PCMS) and pure Na-PCMS were evaluated for their biodegradable character. The Lycopodia fungi were utilized as microorganism and sucrose solution as the growth medium. Biodegradation medium was prepared from fungus Lycopodia sucrose solution. Percent weight loss and SEM photographs showed biodegradation in this graft copolymers and Na-PCMS in order of 32% and 80% respectively. Results are compared with the biodegradation data obtained with previously biodegraded samples. Results are discussed with illustrations.

Introduction

THE use of plastics in packaging and the waste produced have had considerable environmental impact because of the low density and the large amount of most commodity polymers. However, the removal of plastics from the environment is not a viable option, as there would be a dramatic increase in terms of weight and volume using non-plastic packaging and the additional energy consumption would be prohibitive. Recycling of material and energy recovery are obviously primary strategies for reducing plastic waste. Use of biodegradable polymers has advan- ·ɘs.

Renewable sources of polymeric materials and synthetic biodegradable polymers may provide ecologically attractive technologies, but even in countries that are at the forefront of green technology it is only as components of packaging and as natural fiber composites that these materials are currently viable in terms of price and performance. The main constraint on the use of biodegradable polymers for bulk usage is the difference in the use of biodegradable polymers in the price of these polymers compared with that of bulk produced, oil based.

The production of biodegradable polymers with the necessary controlled structure (i.e. monomer sequence, tacticity chirality) to match enzyme specificity in degradation relations in different microbial environments is not possible with current available techniques for chemical synthesis. However, some progress has been made in the synthesis of block copolymers with controlled molecular weight and tacticity. There is, therefore, a potential to make materials with improved physicochemical properties and varied degradation profiles.

Pragmatic definitions of biodegradation concentrate on the degradation of the plastic material without assessment of its ultimate fate and with no attempt at classification in terms of rate. Standards authorities have produced definitions, e.g. ISO 472:1988 ASTM D 20.96 proposal and DIN 103.2.

Many current standard test procedures for biodegradable polymers either describe biodegradability inadequately or fail to provide meaningful practical data, which can be used to make enviromental assessments. The degradation test must incorporate realistic environmental disposal conditions which are either terrestrial (landfill, soil, composting) or aqueous (ground water, marine, water ways, sewage or sediment). The development of some tests is quite advanced, but the standardization of other tests, e.g. comprising with variation in both composition and conditions, is very difficult.

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The increased consumer demand for high quality, long shelf life, ready to eat food has initiated the development of mildly preserved products that keep their natural and fresh appearance as long as possible.[1,2] Edible and biodegradable polymer film offers alternative packaging options advantageous to the synthetic "recalcitrant" packaging polymers because they do not contribute to environmental pollution.[3,4] The potential of polysaccharides and proteins as edible films has long been recognized[5-12], but, apart from some very special applications[13-16], polysaccharides and / or protein based edible films have not found extensive application in the food industry.[17]

The continuously increasing extent of pollution of the environment has recently given rise to a demand for biodegradable polymers, mainly applications related to food packaging and agriculture.[18-20] Thus, in the light of the above context, we had tried to check the biodegradability of 2-HEMA-g-Na-PCMS, a polymeric material and pure Na-PCMS. Na-PCMS is also utilized as a biodegradable constituent in blend composition, [21-23]. The graft copolymer was previously synthesized in our laboratory[24], 2-HEMA-g-Na-PCMS, utilized for the controlled release of bioactive agents.

Here in the process, fixed quantities of 2-HEMA-g-Na-PCMS and pure Na-PCMS were taken in (250 ml) conical flask. Into which was added required proportion of fungal and nutrition medium. We had used Lycopodia microorganisms, sucrose solution and growth medium. The flasks were tightened with cotton plug and kept on a continuous shaker for 1 month. Time to time flasks were removed from the shaker and checked for their weight loss (compared with a biotic control). The graft copolymer and pure Na-PCMS showed degradation confirmed from weight loss and SEM photomicrographs. Ruptured surfaces shown in the micrographs gave evidence of biodegradation. Finally, the data obtained are compared with previously biodegraded graft copolymer with A. Niger[1]

Experimental

Materials

Sucrose from S.D. fine chem. Mumbai, microorganisms from Biosciences Department S.P. University were used. Graft copolymer was used after purification, completely dried Na-PCMS was utilized and cotton used was of surgical grade.

Methods

Growth of microorganism

Sucrose solution was added into flask or growth / nutrition to the Lycopodia for 3 to 4 days to impart required growth of Lycopodia.

Biodegradation

In the process, a fixed quantity (5 gm) of each graft copolymer and Na-PCMS was weighed. It was transferred into a 250 ml conical flask. 10 ml bacteria and 1% sucrose solution was added into the flasks. The flasks were cotton plugged and were kept on a continuous shaker for 1 month. After regular intervals (3 days) 1 flask of graft copolymer and Na-PCMS was removed from the continuous shaker and checked for its weight loss.

Weight loss

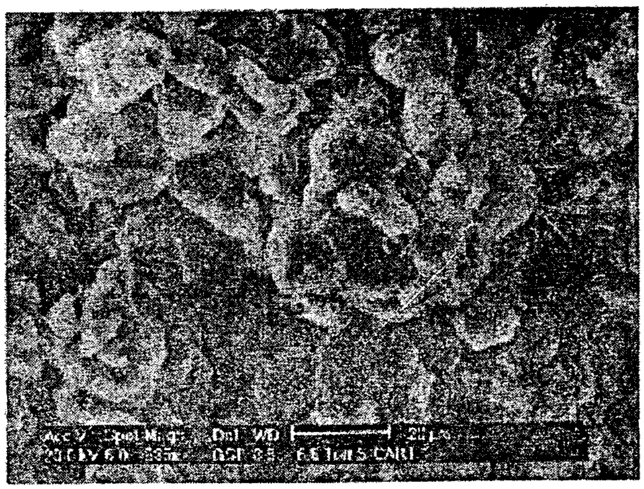
It is an effective means to check whether the biodegradation of graft copolymer and pure Na-PCMS has occurred or not. The content of the flask is filtered with Whatmann filter paper No. 42 and dried in vacuum. The resultant dried material is weighed and weight loss is noted.

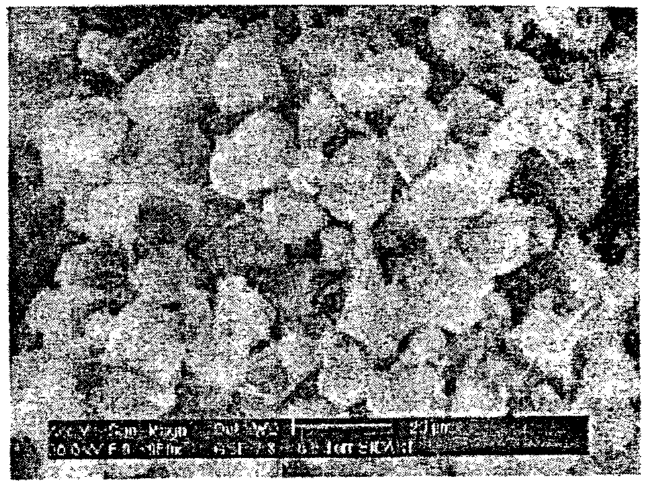
Scanning electron microscopy

A range of different microscopy based techniques have been used to study the surface structure and erosion characteristics during degradatión Philips TM mode SEM was used to get microphotographs. Figure 177S11A and 177S13A shows the SEM micrograph of graft copolymer and Na-PCMS before degradation while 165S3A and 157S4A shows SEM micrograph of graft copolymer and Na-PCMS after degradation.

TABLE 1 : COMPARATIVE DATA OF BIODEGRADATION IN ONE MONTH WITH A. NIGER AND LYCOPODIA

Sr. No.	Time in Days	Weight Loss Lycopodia	Weight Loss Lycopodia	Weight Loss A. Niger	Weight Loss A. Niger
		%	%	%	%
		2 Hema-g-Na-PCMS	Na-PCMS	2-HEMA-g-Na-PCMA	Na-PCMS
1	3	0	5	0	4
2	6	2	15	6	10
3	9	5	22	10	14
4	12	9	28	12	30
5	15	13	30	14	40
6	18	15	47	18	50
7	21	19	55	20	62
8	24	23	62	22	68
9	27	28	72	24	74
10	30	32	80	28	80



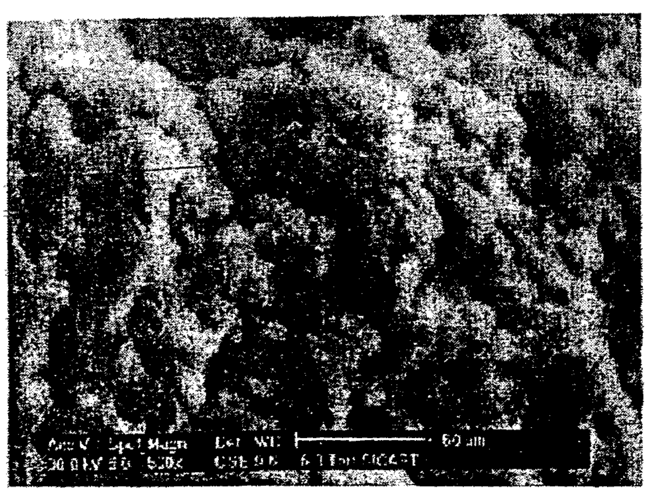


Results and discussion

The aim of the study was to check whether the pure Na-PCMS and graft copolymer are biodegraded or not. We checked Na-PCMS and 2-HEMA-g-Na-PCMS towards the biodegradation. Na-PCMS, a hydrophilic polymer, showed 80% biodegradation. The reason for that may be molecular breakdown and / or that starch served as a source of carbon required for the growth of Lycopodia. So we may observe the significant weight loss in Na-PCMS.

Now the novel graft copolymer 2-HEMA-g-Na-PCMS showed only 32%. It may be due to the less moiety of Na-PCMS available as source of carbon to the Lycopodia. Further, the chemical bond between Na-PCMS and 2-HEMA polymer may prevent the Lycopodia from degrading the polymer. So a lesser % of biodegradation was observed in the case of 2-HEMA-g-Na-PCMS a graft copolymer.

It is reported that[25] structure of PHB (Poly hydroxy butyrate) granules isolated from bacterial cells can be examined using SEM technique. So we had also analyzed both pure Na-PCMS and 2-HEMA-g-Na-PCMS before and after degradation. The photographs clearly show the ruptured surface of the granules and needle like parts, which gave enough evidence that Lycopodia may impart biodegradation in the pure Na-PCMS and 2-HEMA-g-Na-PCMS.



The comparative data are tabulated in *Table I.* Percent degradation of 2-HEMA-g-Na-PCMS was 32% with Lycopodia, while it was 28% with A. Niger. It was the same 80% for both the cultures in the case of pure Na-PCMS, i.e. Lycopodia and A. Niger. From this we may conclude that comparatively Lycopodia utilized more graft copolymer than A. Niger.

Conclusion

2-HEMA-g-Na-PCMS and pure Na-PCMS was checked whether these two polymers are biodegradable or not. From the results we may assess that Na-PCMS was degraded upto 80% and 2-HEMA-g-Na-PCMS up to 32% with the help of Lycopodia. So weight loss is an effective parameter to check the biodegradability. From the SEM micrographs one may assess that the ruptured surface and needle like parts clearly gave evidence of biodegradation. Comparatively we may say that % biodegradation was less in the case of A. Niger than that of Lycopodia. So these polymers may find application in ecologically attractive technologies. Also they may find application in the field of pharmaceuticals as a biodegradable polymer, viz. resorbable sutures, hard and soft tissue implants and controlled drug delivery systems. So finally it may be concluded that the polymer has a biodegradable character. The results are encouraging and findings are fruitful.

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References

1. P.D. Pandya, N.K. Patel and V.K. Sinha. Under communication IJPAC-2001.
2. S. Guilbert, N.Gontard, and G.M. Gorris, *Prolongation of the Shelf life of perishable food products using biodegradable films and coatings,* Lebension. Wiss U. Technol, 29, 1996, P 10-17.
3. E.A. Baldwin, M.O. Nispeos - Carriedo and R.A. Baker, Crit. Rea *Food Sci. Nutr.,* 35, 1995, P 509-524.
4. J.M. Kriochta and (De. Mulder - Johnston, *Food Technol.,* 51, 1997, P 61-24.
5. I. Arvanitoyannis, E. Psomiadou, and A. Nakayama, *Carbohydr Polym.,* 31, 1996, P 179-192.
6. S. Guilbert, B. Biaquet, *Lavoisiez Paris,* 1989 P 320-325.
7. A. Gennadios and C.L. Welter, *Food Technol.* 44, 1990, P 63-69.
8. A. Gennadios, A.H. Brandenburg C.L. Weller and R.F. Testin, *J. Agri Food Chem.* 41, 1993, P 1835-1839.
9. A Gennadios, C.L. Weller and R.F. Testin, *Trans ASAE,* 36, 1993, P 465-470.
10. Ibid, *J. Food Sci.* 58, 1993 P 212-214.
11. D.W.S. Wong, F.A. Gartinean, K. Sgregosski, S.T. Tillin and A.E. Pavlath, *J. Agri Food Chem,* 40, 1992 P 540-544.
12. A.E. Ghaouth, J. Arm & R. Ponnamplalan, and M. Boulet, *J. Food Sci.,* 56, 1991, P 1618-1624.
13. D. Lourdin, G. della Valle and P. Colonna, *Carbohydr Polym.,* 27, 1995, P 261-270.
14. S. Guilbert and N. Gontard, *Royal Society of Chemistry,* Oxford, UK, 1995, P 159-168.
15. J.E. Kinsella Kric. *Rev. Food Sci. Nutr.* 21, 1984 P 197-262.
16. H.J. Park, M.J. Chinnon, and R.L. Shewfort, *J. Food. Sci.* 59, 1994 P568-570.
17. J.W. Park, R.F. Testin, H.J. Park, P.J. Vergano, and C.L. Weller, *J. Food Sci.,* 559, 1994, P916-916.
18. J.J. Kester and O. Fennema, *Food Technol,* 40, 1986, P47-59.
19. G.S. Kumar *Biodegradable Polymers, Prospects and Progress,* Marcel Dekker, New York, (1987).
20. S.J. Huang, *Biodegradable Polymers, in Encyclopedia of polym. sci. and engg.,* Vol. 2 (Wiley, New York). 1985 P220-243.
21. N.K. Patel, P.D. Pandya, and V.K. Sinha, Int. J. Polym. Mater. 2000.
22. N.K. Patel, P.D. Pandya, H. Keharia, H. Patel, and V.K. Sinha, Int. J. Polym. Mater. 2001.
23. N.K. Patel, P.D. Pandya, H. Keharia, H. Patel, and V.K. Sinha, Int. J. Polym. Mater. 2001.
24. Wo Schnabel, *Polymer degradation, Principles and practical applications,* Hanser, Munich, 1981, P 154-177.
25. P.D. Pandya, N.K. Patel, and V.K. Sinha, *Int. J. Polym. Mater.* 49, 2001, P 147-155.