Effect of Radiation and Radiochemical Sterilization on the Polymer Properties of Absorbable Electrospun Constructs

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Introduction—Electrospinning has been used recently in preparing microporous constructs for pharmaceutical applications[1,2]. With recent demands for different forms of microporous absorbable scaffolds for use in tissue engineering, electrospinning took center stage as a process that deserves signifigant attention. This, and Poly-Med's continued interest in absorbable polymers having a broad range of properties that can be uniquely valuable in several pharmaceutical and biomedical applications, prompted the pursuit of a broad-based program dealing with the effect of sterilization protocols on the properties of typical microfibrous constructs produced using a basic electrospinning procedure. Accordingly, this segment of the study deals with (1) the effect of electrospinning on physical properties of a crystalline, absorbable, linear thermoplastic polyester and a polyaxial elastoplastic copolyester, and (2) how the traditional gamma sterilization and novel radiochemical sterilization (RCS) alter the polymer properties of crystalline, absorbable, linear thermoplastic polyester and two similar polyaxial elastoplastic copolyesters with different hydrolytic stabilities.

Materials and Methods—Polycaprolactone (PCL), (Dow Chemical) was used as a highly crystalline, linear, "absorbable" polyester. Two crystalline, absorbable, segmented copolyesters, made as described earlier by end-grafting *l*-lactide onto an amorphous polyaxial polymeric initiator, were used as polyaxial elastoplastic copolyesters (P-2 and P-6)[3,4], with P-6 having an increased hydrolytic instability over P-2. The three materials were electrospun at 20% w/v in 1:1 dichloromethane:chloroform solutions with a voltage differential of 15kV and a Tip-to-Collector distance (distance between the extruder and collector unit) of approximately 7 in. at a rate of 0.2mL/min, using an electrostatic spinning unit constructed in house. Electrospun microfiber constructs with a thickness of 1mm were prepared and characterized for identity (FTIR), thermal properties (DSC), molecular weight (GPC and viscometry), and morphology (SEM). To study the effect of sterilization, samples of the three materials were γ-sterilized with about 20 and 25 kGy dose γ-radiation and radiochemically sterilized using about 5, 10 and 15 kGy dose γ-radiation in the presence of radiochemically generated formaldehyde gas.

Results and Discussion—The experimental results summarized in Table I indicate that (1) the molecular dimensions of PCL are slightly affected by increasing γ-radiation dose without changing the thermal properties; (2) chain degradation of the polyaxial P-2 is responsible for slightly more uniform crystallite size, as reflected in the decrease in W_{hh}, and (3) chain degradation of the more radiation-sensitive P-6 leads to more crystallizable chains with more uniform crystallite size, as indicated by the general increase in ΔH_f and decrease in W_{hh}, respectively, with a maximum at 20kGy after which the degradation reduces the material's ability to crystallize. In addition, the thermal properties of P-2 remained relatively unchanged compared to P-6 which relfects the increased crystallite stability in P-2 compared to P-6.

The molecular dimension in all cases decreased with increasing levels of γ-radiation. PCL showed the highest level of stability, with approximately 20% reduction in M_n and 6% reduction in viscosity over the dose range. P-2 and P-6 showed an increase in molecular dimensions with 5 kGy dose and a 29% and 40% reduction in M_n between 5 and 25 kGy doses of γ-radiation, which is mirrored in similar drops in viscosity. This is further evidence of the increased stability of P-2 over P-6, with the linear material PCL being the most stable of the three.

Table I. Effect of Radiochemical and Radiation Sterilization on PCL, P-2 and P-6 Microfiber Constructs

Material	γ-levels, kGy	DSC[a]			Viscosity[b], dL/g	GPC		
		Melt Temp, °C	ΔH_f, J/g	W_{hh}, °C		M_n, kDa	M_w, kDa	PDI
PCL	0	61.3	93	5.7	1.14	103	160	1.55
	5	61.7	103	6.1	1.14	98	155	1.58
	10	61.6	105	6.0	1.10	92	151	1.64
	15	61.3	109	6.0	-	89	146	1.64
	20	61.5	110	6.0	1.07	86	144	1.69
	25	61.7	104	7.0	1.07	81	140	1.73
P-2	0	161	27.4	6.9	1.04	80	220	2.75
	5	161	27.3	6.9	1.02	90	228	2.53
	10	162	25.7	6.6	0.93	82	212	2.59
	15	162	25.0	6.4	-	72	190	2.64
	20	162	28.8	6.3	0.85	72	183	2.55
	25	162	26.2	6.2	0.81	64	176	2.74
P-6	0	151	8.2	15.4	1.61	128	355	2.78
	5	152	8.8	14.1	1.42	137	389	2.83
	10	155	9.9	13.3	1.27	114	316	2.76
	15	156	10.7	14.2	-	104	293	2.81
	20	156	10.6	13.8	1.06	95	276	2.91
	25	157	6.9	12.8	0.99	82	260	3.17

[a]At 20°C/min heating rate, W_{HH} is the width of the endotherm at half of its height. [b]$CHCl_3$ as solvent

Conclusion—Absorbable linear and segmented polyaxial electrospun polymeric constructs can be radiochemically sterilized without significantly compromising their physical properties. Increasing levels of γ-sterilization increase the extent of change to the polymer properties, which correlates with the polymer hydrolytic stability and possibly the chain geometry.

References

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