Electrospinning of Biopolymers and Biopolymer Blends

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ABSTRACT

Electrospinning can be used to create nanofiber mats of diverse polymers and other materials. Especially "Green Electrospinning", i.e. nanospinning from aqueous or other nontoxic, environmentally-friendly solutions, has gained more and more interest in recent years. In products from "Green Electrospinning", no organic or other critical solvents can remain, allowing for applying such nanofiber mats for tissue engineering or biomedical purposes. Our article depicts some examples of biopolymers electrospun from aqueous solutions and describes the challenges and chances of this process.

KEY WORDS: Biopolymers, electrospinning, gelatin, nanospinning.

1. INTRODUCTION

In the electrospinning process, chemical and physical parameters of the resulting nanofiber mats can be tailored by the chosen materials and the spinning parameters. Especially biopolymers offer a broad variety of interesting intrinsic properties. Aloe vera, e.g., increases wound healing, works antiseptic and anti-inflammatory and supports collagen cross-linking. Chitosan is known to be hemostatic, bactericidal and fungicidal. Alginate can absorb large amounts of wound fluid and can thus be used for drying bleeding wounds.

Gelatin nanofibers belongs to the materials applied in cardiac tissue engineering, while blending poly(glycerol sebacate) nanofiber mats with gelatin has been shown to increase biocompatibility and promote cell proliferation. Agar-agar, on the other hand, is a typical medium for cell growth in biotechnology. Nevertheless, it is only scarcely tested in electrospinning, mostly with solvents different from water and blended with other polymers. There are even reports about agar not being spinnable as a pure material from aqueous solution. Both these materials are thus obvious candidates as substrates for colonization with diverse cells, algae etc.

This article reports on experiments of needleless electrospinning both materials, partly combined with poly(ethylene oxide) (PEO) as a spinning agent.

2. EXPERIMENTAL

The needleless nanospinning machine "Nanospider Lab" (Elmarco, Czech Republic) was used for electrospinning. The spinning parameters were as follows: voltage 70-80 kV, current 0.07-0.10 mA, carriage speed 100-125 mm/s, substrate speed 0 mm/min, nozzle diameter 0.9 mm, electrode-electrode distance 240 mm, electrode-substrate distance 50 mm, relative humidity in the chamber 34-40 %, temperature 22-23°C.

Polymer solutions were prepared from different materials: commercial agar-agar 15 % in aqueous solution; commercial gelatin powder (as used for baking) 15 % in aqueous solution; commercial gelatin leaves 15 % aqueous solution; and pure gelatin powder (from Abtei, Germany) 55 % in aqueous solution. In some experiments, the latter was blended with 19 % wax (Kahl Wax 6592) to increase water resistance.

As a spinning agent, PEO with a molecular weight of 600,000 daltons (concentration 8 %) purchased from S3 Chemicals was used in some experiments. The concentrations of the spinning solutions were chosen due to their viscosity which must not be too high for needleless electrospinning.

3. RESULTS

Due to reports in the literature of agar not being spinnable solely, first tests were performed adding 10 % PEO solution to the agar solution. This test resulted in a very fine nanospun mat. The experiment had to be stopped when the temperature of the agar solution decreased so strongly that the viscosity became too high for spinning.

The same result was found when mixing agar and PEO solutions 1:1 and pre-heating all parts of the spinning equipment which came in contact with the spinning solution. After applying 2 layers, each of which was spun for 15 min., a solid nanofiber mat was produced. The resulting fibers are depicted in Fig.1. Apparently, they are quite straight and even and form a well-linked network.

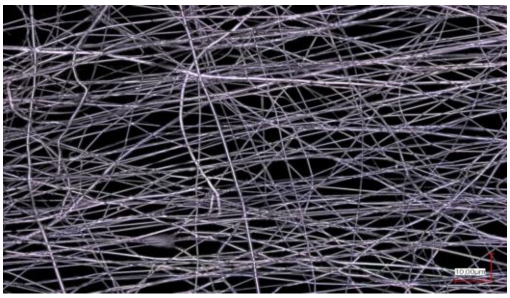

Fig.1. Nanofiber mat from pure agar

The gelatin powder solution was also mixed with 10 % PEO solution. Opposite to the agar-PEO solution, a strong foam generation could be observed here which could only partly be reduced by ultrasonic treatment. This resulted in an increased viscosity, impeding the spinning process.

Performing the same experiment with gelatin leaves resulted in the irregular nanofiber mat depicted in Fig.2. The extreme differences of the fibers in different areas indicate the possibility of an incomplete mixing of both material solutions.

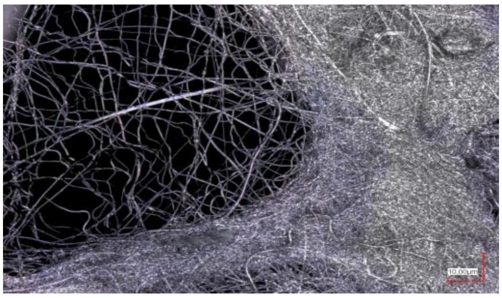

Fig.2. Nanofiber mat from gelatin leaves / PEO solution

Due to this problem, the next test was performed using pure gelatin leaves solution. Interestingly, the produced nanofiber mat was much more regular than the one produced by co-spinning gelatin with PEO.

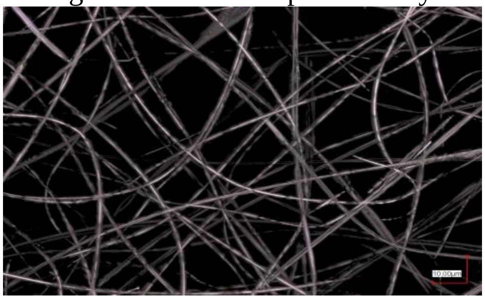

Fig.3. Nanofiber mat from pure gelatin in aqueous solution

To increase the result further, pure gelatin was firstly tested combined with different amounts of PEO solution, again not resulting in fiber formation. Without the PEO, however, a dense, thick nanofiber mat was produced which is depicted in Fig.3. This mat could easily be drawn from the substrate without damaging it. Apparently, this recipe can be used to create stable gelatin nanofiber mats which can be developed further for applications in medicine or biotechnology.

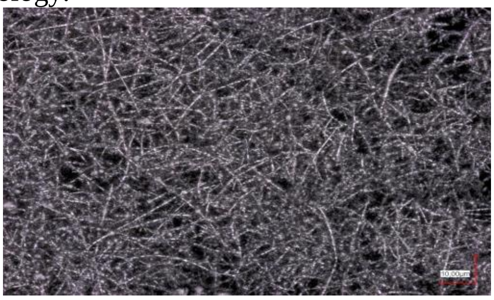

Fig.4. Nanofiber mat from pure gelatin blended with wax

To increase water resistance of this material, it was combined with wax. Fig. 4 depicts the resulting nanofiber mat. Interestingly, the addition of wax changed the morphology of the resulting nanofiber mat significantly, resulting in a strongly increased fiber density and a “coating” of the fibers with wax droplets. Due to this incomplete covering of the fibers instead of the desired blending, the water resistance of the nanofiber mat was not significantly increased. Thus, in future tests different nontoxic possible crosslinking agents will be tested to create a completely “green” gelatin nanofiber mat.

4. CONCLUSION

To conclude, we have shown possible ways to achieve pure gelatin and agar/PEO blended nanofiber mats by “Green Electrospinning” from aqueous solutions. Blending gelatin with PEO or wax significantly modified the mat morphology. Future research is necessary to increase water resistance of both materials in an eco-friendly way with nontoxic crosslinking agents.

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