Carbohydrate Polymers 109 (2014) 16–21

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Short communication

Process optimization for fabrication of gellan based electrospun nanofibers

Priya Vashisth, Parul A. Pruthi, Rajesh P. Singh, Vikas Pruthi*

Department of Biotechnology, Indian Institute of Technology Roorkee, Roorkee 247667, India

ARTICLE INFO

Article history:
Received 26 January 2014
Received in revised form 3 March 2014
Accepted 4 March 2014
Available online 26 March 2014

Keywords:
Nanofibers
Gellan
Electrospinning
Polyvinyl alcohol

ABSTRACT

In this investigation, the nanofiber formation ability of gellan, a FDA approved low cost natural polysaccharide, has been achieved for the first time using electrospinning technique. The gellan based ultrafine nanofibers were fabricated by using a blend mixture of gellan with another biodegradable polymer polyvinyl alcohol (PVA). The morphology of resulting gellan–PVA nanofibers was analyzed using field emission scanning electron microscopy (FESEM). The mass ratio of 50:50 for gellan:PVA was recorded as an optimum solution ratio to obtain uniform bead free nanofibers with an average diameter of 40 ± 15.8 nm. Data depicted that among different parameters evaluated, viscosity and the mass ratio of gellan:PVA were the key parameters that influence the nanofiber morphology and diameter.

1. Introduction

Electrospinning is a versatile, progressive and widely used technique for making the highly porous nano-scale fibers. The high surface area-to-volume ratio of these electrospun nanofibers make them a potential candidate for a broad range of biomedical applications such as tissue engineering, wound healing and drug delivery (Homayoni, Ravandi, & Valizadeh, 2009; Vashisth et al., 2013). Recently carbohydrate polymers (Bhattarai & Zhang, 2007; Toskas et al., 2013) have taken an edge over their synthetic counterpart due to their abundant nature and unique structural characteristics. Gellan is a natural exopolysaccharide obtained from *Sphingomonas elodea* (Gong et al., 2009). Its chemical structure consists of repeating tetrasaccharide units of two D-glucose, D-glucuronic acid and L-rhamnose in a linear fashion. The advantageous properties of gellan as biomaterial include the cytocompatibility, bio-adhesiveness and presence of free carboxylic group (Silva-Correia et al., 2011). Moreover, gellan hydrogels (Gong et al., 2009), gellan films (Lee, Chen, & Tsao, 2010; Li, Kamath, & Dwivedi, 2001), gellan microcarriers (Agnihotri, Jawalkar, & Aminabhavi, 2006; Wang, Gong, Lin, Shen, & Wang, 2008) have been proved as a prospective material for biomedical engineering. However, despite huge range of applications, it is potential as gellan nanofibers have not been explored till date to best of our knowledge. This could be due to the limited solubility and the very high viscosity of gellan solutions. Like, most natural polysaccharides, gellan also shows a complex sol–gel behavior and a non-typical solvation in water (Liu, Wang, Gao, & Bai, 2013) which make it difficult to electrospun. Earlier, Stijnman, Bodnar, and Tromp (2011) have tried to electrospun 1% aqueous gellan solution but were unsuccessful to produce gellan fibers. They reported that, instead of jet formation, the gellan solution produced only deformed droplets and an unstable Taylor cone at the spinning needle tip. This behavior of gellan solution was found to be due to its anionic nature, low or a high low-shear viscosity and strong shear thinning behavior at low-shear rates. These limitations were circumvented by adding another hydrophilic co-biopolymer PVA as a supporting polymer. In present study, the effects of solution parameters (viscosity, surface tension, specific gravity and mass ratio of polymers) along with process parameters (voltage, flow-rate, tip-to-collector distance) on the gellan–PVA nanofibers formation and on its morphology were evaluated. Here, we highlighted gellan as a novel biopolymer that could be electrospun to fabricate nanofibers useful for tissue engineering, drug delivery and regenerative medicine applications.

2. Experimental

2.1. Materials

Gellan (Gelrite; MW 1000 kg/mol) was purchased from Sigma Aldrich. PVA (Mw = 140,000) was procured from Himedia (India). Deionized water (diH_2O) was used throughout to prepare polymeric solutions.

* Corresponding author. Tel.: +91 1332285530.
E-mail addresses: vikasfbs@iitr.ernet.in, vikasfbs@gmail.com (V. Pruthi).

http://dx.doi.org/10.1016/j.carbpol.2014.03.003
0144-8617/

Table 1
The composition and properties of gellan–PVA solutions.

Sample code	Solution composition[a] (wt%)			Solution properties		
	Gellan	PVA	Gellan–PVA ratio	Viscosity (mPaS)	Surface tension (mN/m)	Specific gravity
G1	1.5	10	100:0	5339 ± 74.7	52.7 ± 0.07	1.010
G2	1.5	10	90:10	5255 ± 80.8	52.4 ± 0.01	0.992
G3	1.5	10	70:30	4727 ± 142.5	51.8 ± 0.00	0.986
G4	1.5	10	50:50	4067 ± 41.6	49.9 ± 0.05	0.971
G5	1.5	10	30:70	2675 ± 60.5	49.3 ± 0.05	0.897
G6	1.5	10	10:90	2591 ± 41.8	48.4 ± 0.00	1.012
G7	1.5	10	0:100	2292 ± 22.2	48.0 ± 0.00	0.972

[a] The solvent was deionized water.

2.2. Solution preparation

Gellan (1.5 wt%) and PVA (10 wt%) solutions were prepared by dissolving them separately in diH_2O. Gellan–PVA blend solutions with different blend ratios (0:100, 10:90, 30:70, 50:50, 70:30, 90:10 and 100:0) were prepared. All the prepared solutions were degassed before use.

2.3. Electrospinning

Nanofibers fabrication from the prepared solution was achieved by applying a high voltage power ranging from 15 to 21 kV to the metallic needle (21 G), attached to 3 ml syringe at the flow-rate from 0.1 ml/h to 0.4 ml/h, controlled by a syringe pump (Harvard apparatus 11 plus syringe pumps). Aluminum foil was used to collect the nanofibers with the horizontal distance ranging from 6 to 18 cm from the needle tip. All the electrospinning processes were carried out under ambient conditions (temperature 25 ± 2 °C, relative humidity 30 ± 1%). The electrospun nanofibers were dried overnight in desiccator to facilitate complete removal of any residual solvent.

2.4. Characterization

The shear viscosities of the gellan–PVA blend solutions were measured at different revolutions (3–120 rpm) using Brookfield viscometer (DV-II pro) with LV-4 spindle. Surface tension and specific gravity of these solutions were determined using du-Novy tensiometer (KRÜSS GmbH, Germany) and specific gravity bottle (25 ml), respectively. The surface morphology of electrospun gellan–PVA nanofibers was examined using FESEM (Ultra Plus 55, ZEISS). For FESEM analysis, the nanofibrous samples (10 mm × 10 mm) were coated with a thin layer of gold using sputter coater (Biotech SC005) for 60 s. The average diameters of the nanofibers were calculated at 50 different points from the FESEM images using Image J software.

3. Results and discussion

3.1. Electrospinning

Electrospinning employs the usage of electrostatic forces to draw fibers from the solution and particularly suited for the production of nano-sized fibers from the large complex molecules. This process is affected by several solutions and process parameters (Vashisth et al., 2013). In the present study, the solution parameters such as concentration, viscosity, surface tension and specific gravity were optimized for fabrication of gellan–PVA nanofibers as listed in Table 1. The viscosity and surface tension of gellan based solutions were observed to be enhanced with increased proportion of gellan in gellan–PVA blend solution, whereas the specific gravity of the solutions changed irrelevantly. Our findings revealed that the aqueous solution of gellan alone at any concentration is not able to produce any fibrous structure using electrospinning

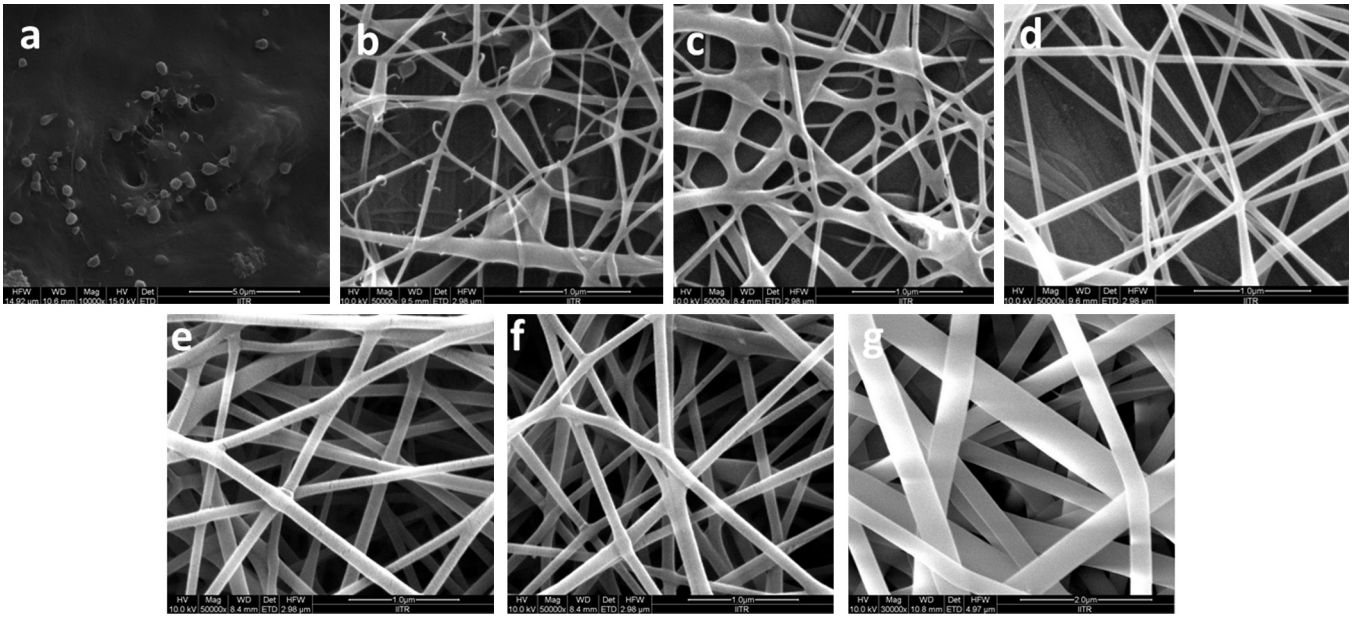

Fig. 1. Morphology of the gellan–PVA nanofibers fabricated at varying gellan:PVA ratio in the blend solutions (a) 100:0, (b) 90:10, (c) 70:30, (d) 50:50, (e) 30:70, (f) 10:90 and (g) 0:100.