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Prospect of biobased antiviral face mask to limit the coronavirus outbreak

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ABSTRACT

The rapid spread of COVID-19 has led to nationwide lockdowns in many countries. The COVID-19 pandemic has played serious havoc on economic activities throughout the world. Researchers are immensely curious about how to give the best protection to people before a vaccine becomes available. The coronavirus spreads principally through saliva droplets. Thus, it would be a great opportunity if the virus spread could be controlled at an early stage. The face mask can limit virus spread from both inside and outside the mask. This is the first study that has endeavoured to explore the design and fabrication of an antiviral face mask using licorice root extract, which has antimicrobial properties due to glycyrrhizinic acid (GA) and glycyrrhizin (GL). An electrospinning process was utilized to fabricate nanofibrous membrane and virus deactivation mechanisms discussed. The nanofiber mask material was characterized by SEM and airflow rate testing. SEM results indicated that the nanofibers from electrospinning are about 15–30 μm in diameter with random porosity and orientation which have the potential to capture and kill the virus. Theoretical estimation signifies that an 85 L/min rate of airflow through the face mask is possible which ensures good breathability over an extensive range of pressure drops and pore sizes. Finally, it can be concluded that licorice root membrane may be used to produce a biobased face mask to control COVID-19 spread.

1. Introduction

The emergence of coronavirus and its rapid spread across the globe has led to a large epidemic and pandemic. In response, many countries have initiated prodigious non-pharmaceutical activities like lockdowns, social distancing, and closure of educational institutions. It will be beneficial for people if an appropriate face mask can be designed that can inactivate the virus itself. During coronavirus (SARS-CoV-2) infections, the face mask is crucial in preventing transmission (Johnson et al., 2009). It has been reported that face masks are effective in lowering the spread of the virus. (Jiang et al., 2020; Liu and Zhang, 2020; Liang et al., 2020; Hu et al., 2020). SARS-CoV-2 is spread through airborne droplets and, in some cases, aerosols containing the virus. Respiratory droplets transmission is a serious concern due to the rapid spread and circulation of SARS-CoV-2 in humans (Richard et al., 2020).

Face masks can filter droplets containing the virus. Many countries are not yet fully prepared for disease control at this magnitude and may not be able to prevent transmission efficiently. In this regard, a vaccine can comprehensively reduce mortality. However, potential vaccines are still in the trial stage. In this situation, masks can significantly prevent any microbes. Thus, the use of personal respiratory masks may be an effective way to reduce transmission of COVID-19 However, face masks that are currently available in the market may not reduce the transmission of the virus in the community because they are not used...
correctly. It would be better and advantageous to reduce the transmission of the virus if the face mask itself could damage the virus. In addition, most current face masks have a pore size which is larger than the virus. It is a major challenge for researchers to inactivate the virus, thus, they are trying to develop a universal virus capturing system.

Nevertheless, face masks become an important global healthcare measure amid the coronavirus pandemic. It is a challenging task during the pandemic to balance the supply of and demand for masks during disease outbreaks. Currently available masks, which are made of non-renewables, are environmentally hazardous and non-biodegradable. The processing of single-use masks made of synthetic polymers produces environmentally damaging microplastics. Therefore, the efficacy of mask disposal must be improved urgently by integrating raw materials that are intrinsically environmentally friendly, lightweight, and disposable and provide a high standard of efficiency at a low cost.

In this circumstance, plants with antimicrobials properties such as oregano, sage, basil, fennel, garlic, and licorice can significantly reduce the spread of coronavirus (Xu and Zhang, 2020). Among these plants, licorice has potentially very powerful antiviral properties (Chirumbolo, 2016). It is a common herb traditionally used in the Asia-Pacific region. Researchers have demonstrated that licorice is effective against RSV, HIV, and SARS-CoV, all of which causes serious pneumonia (Cinatli et al., 2003; Yeh et al., 2013; Fukuchi et al., 2016). Researchers have found that different elements of licorice are responsible for antimicrobial and antiviral activities through various mechanisms. Licorice contains around 300 flavonoids and more than 20 triterpenoids. Among them, two triterpenes, 18-β glycyrrhetinic acid (GA) and glycyrrhizin (GL) have been shown to have antiviral properties and the potential to weaken virus activities (Chirumbolo, 2016). The recent study discloses that the polymeric form of glycyrrhetinic acid leads to excellent antiviral effects (Tong et al., 2020). Therefore, this study aims to develop and assess the porosity of a fibrous three-layered filtration mask made from licorice root membrane. No study on the development of biobased face masks using licorice root membrane was found in the literature. Therefore, it is expected that the outcome of this research will guide researchers, scientists and policymakers to develop biobased antiviral face masks to reduce the spread of COVID-19.

2. Experimental procedure

2.1. Materials

In this study, licorice root was used to fabricate the nanofibers due to its viral inactivation compounds including GL and GA, which possess an antimicrobial capacity. Nanofibers destroy the virus by releasing GL and GA via contact inhibition or immobilization. Plants have been utilized for drug development, thus, it would be expedient to investigate and characterize the possible fusion of the active elements of these plants for anti-viral applications. Licorice nanofibers can be assembled for increased protection against COVID-19. Polyvinyl alcohol (PVA) is a biocompatible nontoxic, highly hydrophilic semi-crystalline polymer with remarkable properties such as water solubility, strength, gas permeability, and thermal characteristics (Park et al., 2010). PVA solution has been used broadly in the electrospinning process because of its ability to produce biodegradable mats and ultrafine separation filters. PVA solution helps the formation of excellent quality nanofibers in electrospinning.

2.2. Preparation of licorice root and nanofibrous

Licorice roots were washed thoroughly with mineral water, ground and then immersed into methanol from Sigma-Aldrich (NS: M = 1:2) for 8 h for extraction. The extracts were filtered twice through a quadruple layer of nylon mesh fabric and then evaporated at 70 °C while being magnetically stirred until a jelly of NS polymer formed. In addition, 10g polyvinyl alcohol (PVA) with a molecular weight (MW) of 115,000 DP of 1700–1800, viscosity: 26–32cps, 99% hydrolyzed granules were sourced from Loba chemical (India). PVA was mixed with 90 mL deionized water to obtain 10 wt % (w/v) solution. This mixture was stirred and heated to 80 °C to attain a clear, highly soluble and transparent solution. Next, 14g of licorice extract was mixed with 30 mL PVA solution to prepare the final solution for electrospinning.

2.3. Electrospinning

An electrospinning machine (model TL-01, TONG LI TECH) produced the nanofibrous membrane using PVA and licorice root extract under optimized processing parameters. Fig. 1 depicts the process from licorice root extract to mask design. The prepared solution was transferred to a plastic syringe attached to a capillary tip with an inner diameter of 22 gauge (0.64 mm). The plastic syringe was placed at a 45° angle and the distance between the collector and capillary tip was maintained at 15 cm. The copper wire attached to a positive electrode at 23 kV was inserted into the solution and a negative electrode at 12 kV was connected to a metallic collector. The solution pumping rate was fixed at 4 mm/h.

2.4. Airflow rate calculation

The measurement of airflow through the pores of the mask is important to determine the functionality of the mask. The airflow rate $Q$ (m$^3$/s) has been calculated using equation (1) while the air mean velocity $U_m$ (m/s) has been determined using equation (2) (Hes and Dolezal, 2017).

$$Q = mA_U_m$$

$$U_m = \frac{\Delta P \rho g}{2\eta m}$$

Where, $\Delta P$ is the pressure drop across the face mask, $d_p$ is the diameter of the mask pore, $\eta$ is the air dynamic viscosity (Pa.s), $h$ is the pore length (m), $A$ is the mask area (m$^2$), and $m$ is the number of the pores. The air dynamic viscosity was taken at 30 °C. The $\Delta P$ is maintained at 340 Pa and the thickness of the face mask is maintained at 2 μm. To simplify the estimation, the shape of the pore is considered circular due to the nanoscale range. Additionally, it has been assumed that the airflow is laminar and the effects of friction is negligible.

3. Results and discussion

The mechanism of virus deactivation is shown in Fig. 2. The topography of fabricated nanofibrous membrane shows that sneezed microdroplets can be easily captured and inhibited. Cinatli et al. (2003) report that the most active compound of licorice root in inhibiting the SARS related virus is glycyrrhizin. Glycyrrhizinic acid (GLR), a triterpenoid saponin, is mainly isolated from licorice root, which is effective against a variety of human viruses (Ashfaq et al., 2011). The study by the researcher (Bailly and Vergoten, 2020) shows clear evidence that glycyrrhizinic acid isolated from licorice has antiviral properties that can deactivate the virus and stop replication. Droplet microbes are locked on the agent and infectious droplets are rapidly opened by hydrophilic action leading to exposure of viruses. The trapping and inhibiting properties of the licorice root inactivates the virus quickly. GL and GA are capable of damaging biomolecules such as portions, lipids and DNA (Chowdhury et al., 2020).

Surface morphology of the licorice root fibrous membrane was estimated using SEM (Hitachi VP-SEM SU 1510, Japan), as shown in Fig. 3. From the SEM image, electrospinning membranes are uniformly distributed into a network structure that enhances the contact area. Thus, the electrospinning membrane can enhance the ability of anti-interference of airflow and increase the radical trapping effect. The
nanofibers from electrospinning were about 15–30 μm in diameter with random porosity and orientation as shown in Fig. 3(b) and (d). The distance between the fibres is about 2–5 μm and pores are formed in the meshwork which signifies a high air permeability. From Fig. 3(c) shows that active substances were distributed uniformly in an array of the membrane. Nearly 27 μm course surfaces would be beneficial for capturing and killing the virus in droplets accelerated through the mask. The particle detection Fig. 3(c) shows that a licorice root particle density of about 0.021 particles/mm² was detected, which signifies that a maximum amount of the licorice roots was formed to nanofibers.

Fig. 4 (a) shows that the airflow rate is increased with an increasing pore size, which signifies that the breathability of the mask membrane is improved because of the improved porosity of the mask membrane. It is also worth mentioning that the pore size of 75 nm, which is smaller than the size of COVID-19, is needed to maintain a good breathability of 85 L/min (Kim et al., 2015). Moreover, the fabricated membrane allows good breathability across an extensive range of pressure drops as shown in Fig. 4(b). A higher airflow resistance signifies a higher pressure drop.
that reduces the breathability of the face mask (El-Atab et al., 2020). In this situation, an increasing airflow rate would not influence the filtration efficiency if the pore size of the mask membrane were maintained at a size smaller than the size of COVID-19 as a consequence of the straining mechanism (Liu et al., 2015). Increasing the airflow rate affects the filtration efficiency if the pore size is larger than the particle size as for an N95 face mask with a pore size of 300 nm.

4. Conclusion and future perspective

Most countries in the world have taken many precautionary measures against COVID-19. Government officials have been continuing to make efforts to reduce crowds in public places and many steps have been taken to ensure people’s safety such as social distancing, reducing public transport, and the shutdown of offices and factories. This may reduce COVID-19 cases, but the economic crisis is still going to worsen. To avoid the spread of COVID-19 and ensure a sense of protection and wellbeing for all, personal hygiene must be preserved until an effective vaccine is produced. The face mask is one safety measure and there is a significant rise in the use of face masks every day, numbering in the millions, resulting in a high demand for materials. In this paper, we have proposed the potential of the licorice root membrane as a nanofiber that can be used in the production of a face mask. The porosity of the proposed mask is less than the size of COVID19, thus, it is believed that this mask can help to prevent the spread of the virus.

Despite significant findings on the potential of licorice root membrane as a raw material for face masks, some limitations remain. For example, the performance of a mask depends on the fluid-resistant, bacterial filtration and particulate filtration capacities. Therefore, further comprehensive research is still necessary to explore these variables and give a clearer picture of their virus-resistant capacity.
Author contribution

Mohammad Asaduzzaman Chowdhury: Conceptualization, Supervision. Md Bengir Ahmed Shuvho: Writing - original draft, Formal analysis. Md Abdus Shahid: Investigation, Formal analysis. A.K.M. Monjurul Haque: Methodology, Supervision. Mohammad Abul Kashem: Investigation, Supervision. Su Shiung Lam: Writing - review & editing. Hwai Chyuan Ong: Writing - review & editing. Md. Alhaz Uddin: Writing - review & editing. M. Motijur: Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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