Desing of Smart Electrospun Oxygen Sensors for Food Quality and Safety

Meryem Yılmaz, Aylin Altan
Department of Food Engineering, Mersin University, Mersin, Turkey

Oxygen sensors from intelligent packaging systems can be used to detect the integrity of packaging, to verify the effectiveness of oxygen absorbers, to provide traceability in the food production and consumption chain, and to monitor the quality and safety of packaged food. For this reason, the aim of this work was to design nanofiber based UV-activated visible colourimetric oxygen sensor by electrospinning.

A completely hydrolyzable poly(vinyl alcohol) (PVA) was used for the oxygen sensor design. Oxygen detection solutions, consisting of compounds such as methylene blue, glycerol and titanium dioxide, were prepared for the oxygen sensitive sensor structure. Single needle and coaxial electrospinning methods were used for the production of the sensor. In single needle electrospinning method; the PVA solution prepared at 12% concentration was mixed with the oxygen detection solution. In the case of coaxial electrospinning, oxygen detection solution was used as core solution with a shell solution of 12% PVA. The voltage applied was changed from 17-21 kV and 19-24 kV while the distance between the needle and the collector was in the range of 14-17 cm and 17-21 cm for the single needle and coaxial electrospinning methods. The morphology of the produced nanofibers was determined by imaging using a field emission scanning electron microscope. In order to test the designed sensor, the produced membrane was cut into 2x2 cm and placed in the packaging material. Then the air inside the packaging material was replaced with nitrogen gas. The sensor in the prepared packaging material was activated at 254 nm under UV light. The response of activated sensor was monitored as the time required to change the color of membrane when oxygen was present inside the package.

In the first part of this study, effects of PVA concentration, solvent type and mixture of different solvents (water, acetic acid, ethanol) were studied in order to obtain nanofiber from the fully hydrolyzed PVA polymer (Table 1). SEM results showed that 12% PVA solution prepared in 25:75 acetic acid-water produced the uniform fiber distribution. In the second part of this study, electrospinning of oxygen detection solution and PVA polymer solution was carried out using both single needle and coaxial electrospinning methods. In the coaxial electrospinning method, colorful nanofibrous membrane could not be obtained due to the encapsulation of oxygen detection solution within PVA polymer (Figure 1a). However, blue colored nanofibrous membrane was produced using a single needle electrospinning (Figure 1b). Diameters of the nanofibers produced by a single needle electrospinning varied from 480 to 850 nm. The produced nanofiber membrane was exposed to UV light after it was packaged. Thus, the color of the membrane was returned from blue to white in about 20 seconds. The color remained stable in oxygen free environment (Figure 1c). However, sensor was returned completely to its original color in about 85 seconds when air entered inside of the food package (Figure 1d). Results showed that the sensor developed could be controlled directly by human eye and have rapid UV light activation and fast oxygen response. These properties of sensor can provide a quick control of product and therefore people can see whether the packaged food has entered the process of disintegration during the shelf life.

The designed oxygen sensor can be used to produce improved food packages which provide the most suitable conditions for food quality and safety in active, intelligent and MAP systems. In this regard, the sensors developed by the electrospinning process may yield new applications in prevention of losses and providing food safety.

Acknowledgements: This project was supported by the Research Fund of Mersin University (MEÜ BAP) with Project Number 2017-2-TP2-2371.

Keywords: intelligent nanofibers, oxygen sensor, electrospinning, intelligent packaging systems