JRIFST

www.journals.rifst.ac.ir
Journal of Research and Innovation
in Food Science and Technology

Research Institute of Food Science and Technology

Volume 8, Issue 1, Spring 2019, Pages 79-90
Document Type: Extended Abstract
DOI: 10.22101/JRIFST.2019.04.30.817

Extended Abstract

Preparing of Bacterial Cellulose/Polypyrrole-Zinc Oxide Nanocomposite Film and Studying its Physicomechanical, Antimicrobial and Antioxidant Properties

Sajad Pirsa[1*], Tohid Shamusi[2], Ehsan Moghaddas Kia[3]

1- Associate Professor, Department of Food Science and Technology, Faculty of Agriculture, Urmia University, Urmia, Iran
* Corresponding author (Pirsa7@gmail.com & S.pirsa@urmia.ac.ir)
2- MSc. Graduated, Department of Food Science and Technology, Afagh Higher Education Institute, Urmia, Iran
3- Assistant Professor, Department of Food Science and Technology, Maragheh University of Medical Sciences, Maragheh, Iran

Received: 2018.06.12; **Accepted**: 2018.09.22

Abstract
In this research, polypyrrole (PPy) and polypyrrole-zinc oxide (PPy-ZnO) nanocomposites were synthesized by chemical method on the bacterial cellulose film in the presence of Iron chloride III. The size, shape and morphology of the synthesized particles were studied using scanning electron microscopy. The results showed that the polypyrrole particles (60-150 nm) are spherical in shape, while the nanoparticles of polypyrrole-Zinc oxide are granular in shape and are in the range of 30-120 nm. Mechanical properties including, strain to break and tensile strength and antimicrobial-antifungal properties, as well as antioxidant properties and electrical conductivity of the films were studied. The results showed that the addition of polypyrrole decreased the electrical resistance, resulting in an increase in the electrical current of the film. The addition of nanoparticles reduced the mechanical properties and decreased the tensile strength. The inhibitory power of free radicals of the film increased with the addition of zinc oxide. The synthesis and increase of the polypyrrole synthesis time on a cellulose film had a positive effect on the antimicrobial and antifungal properties of films, but zinc oxide nanoparticles were more effective on antifungal properties.

Keywords: Antimicrobial and Antioxidant Properties, Bacterial Cellulose, Nanostructure, Polypyrrole, Zinc Oxide

Introduction
Increasing the production and consumption of plastics and petroleum polymers in daily life has led to the accumulation of huge amounts of plastic waste and has caused extensive environmental problems. A fundamental solution to the problem of polymer waste is the production of biodegradable polymers (Siracusa, Rocculi, Romani, & Dalla Rosa, 2008).

Bacterial cellulose (BC) is one of the most biodegradable polymers that are recently used in the field of food packaging. Bacterial cellulose is a microbial polysaccharide that has unique properties, and many researchers have focused on the use of this compound in various fields like food and medical industries and electronic applications (Esa, Tasirin, & Rahman, 2014). In this research, bacterial cellulose containing zinc oxide and polypyrrole was produced to be used in active, antifungal and antimicrobial packaging as well as intelligent packaging (due to its electrical resistance to corrosive food). The main objective of this study is to investigate the mechanical properties, antimicrobial properties, antioxidant and electrical conductivity of the produced film.

Material and methods

Pyrrole was prepared from Merck Co. and glycerol, acetic acid, 2, 2-diphenyl-1-picril-hydrazyl 2,2-Diphenyl-l- picrylhydrazyl (DPPH), and other organic compounds used by Merck and Aldrich Company. Scanning electron microscope (SEM) images were recorded using a Tescan Vega-3 scanning electron microscope (Razi Metallurgical Institute, Tehran). The textural meter (TA.XT Plus Stable Micro Systems UK) was used to study the mechanical properties of films. Bacterial cellulose/polypyrrole-Zinc oxide film was prepared according to the central composite design (Table 1).

Table 1. List of experiments in the CCD design

Run order	Factors		
	A: Pyrrole (mol Lit^{-1})	B: ZnO (mol Lit^{-1})	C: Time (min)
F1	0.05	0.05	37
F2	0.10	0.00	37
F3	0.10	0.00	60
F4	0.03	0.08	26.50
F5	0.10	0.00	15
F6	0.00	0.10	15
F7	0.08	0.03	48.50
F8	0.10	0.00	60
F9	0.05	0.05	60
F10	0.10	0.00	26.50
F11	0.10	0.00	60
F12	0.08	0.03	26.50
F13	0.00	0.10	60
F14	0.00	0.10	15
F15	0.05	0.05	15
F16	0.00	0.10	60
F17	0.03	0.08	48.50
F18	0.05	0.05	60
F19	0.00	0.10	37.50
Blank	0.00	0.00	0.00

Results and discussion

The SEM image of a polypyrrole-zinc oxide nanocomposite showed that the particle size is 100-150 nm and is grown on bacterial cellulose. Surface morphology clearly showed that polypyrrole and zinc oxide nanoparticles grow uniformly on the surface of bacterial cellulose. The results of electrical conductivity showed that increasing the pyrrole concentration reduced electrical resistance and increased the electrical current intensity. In intelligent packaging (based on electrical resistance variations), the high electrical conductivity increases the sensitivity of the film to environmental changes. Polypyrrole polymerization time and ZnO deposition time have a significant effect on antioxidant activity. Increasing polymerization and deposition time increases antioxidant activity. Other research results suggested an increase in antioxidant activity of films by adding ZnO particles to the polymer matrix (Emamifar, Kadivar, Shahedi, & Soleimanian-Zad, 2011). Fig. (1) Shows that increasing the concentration of ZnO in the nanocomposite matrix has a significant effect on antioxidant activity (P<0.05).

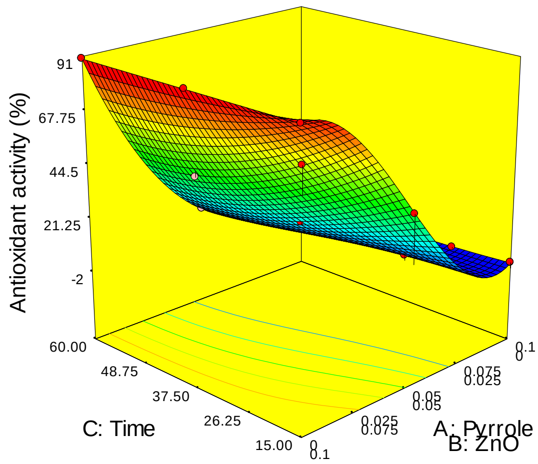

Fig. 1. 3D plot of ZnO and polypyrrole concentration on the antioxidant activity of films

The results obtained from Fig. (2) show that zinc oxide, polypyrrole and zinc oxide-polypyrrole composite is effective on the mechanical properties of bacterial cellulose film. Accordingly, the zinc oxide decreases the strain in the breaking point and the film tensile strength, which can be attributed to the filling of the polymeric chain in the cellulose by zinc oxide, which ultimately causes to reduce flexibility and physical strength.

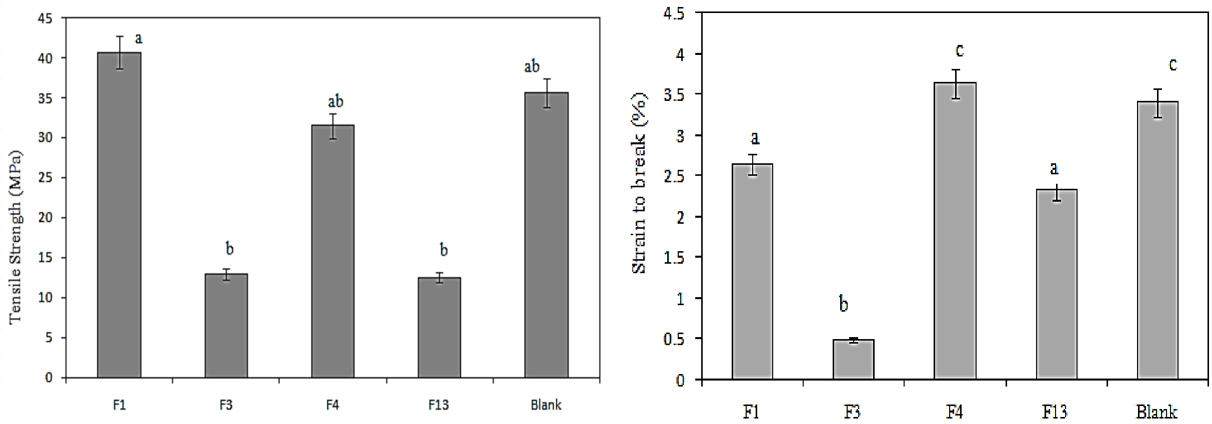

Fig. 2. Strain to break (STB) and tensile strength (TS) of preparted films

Table (2) and (3) shows the antifungal activity of films produced against *Aspergillus Niger* fungi and the antibacterial activity of films in the presence of Escherichia coli. Control film (bacterial cellulose) showed no inhibitory effects on *Aspergillus* and *Escherichia coli* bacteria. The addition of ZnO and polypyrrole led to the creation of clear inhibitory areas around the films. The highest inhibitory was observed in samples containing 0.05% polypyrrole and 0.05% zinc oxide. The cause of this phenomenon is the production of active oxygen species on the surface of nanoparticles, which penetrates the cells of the bacteria causing cell death. The results are consistent with the results of (Nawaz, Solangi, Zehra, & Nadeem, 2011).

Table 2. Antifungal activity of films against *Aspergillus niger*

Run	ZnO (mol Lit^{-1})	Pyrrole (mol Lit^{-1})	Time (s)	Film Thickness (mm)	Diameter of inhibition zone (mm)	Difference in diameter of inhibition zone and film (mm)	Antifungal area (mm^2)
Blank	-	-	-	3	0.00	0.00	0.00
F9	0.05	0.05	60	3	13.50	10.50	86.54±0.12
F13	0.10	0.00	60	3	8.10	5.10	23.74±0.15
F17	0.08	0.03	45	3	5.50	2.50	4.90±0.10
F1	0.05	0.05	45	3	10.00	7.00	38.46±0.08
F19	0.10	0.00	45	3	4.50	1.50	1.76±0.15

Table 3. Antimicrobial activity of films against *Escherichia coli*

Run	ZnO (mol Lit^{-1})	Pyrrole (mol Lit^{-1})	Time (s)	Film Thickness (mm)	Diameter of inhibition zone (mm)	Difference in diameter of inhibition zone and film (mm)	Antibacterial area (mm^2)
Blank	-	-	-	3	0.00	0.00	0.00
15	0.05	0.05	45	3	6.30	3.30	8.54±0.08
9	0.05	0.05	60	3	8.80	5.80	26.40±0.10
1	0.05	0.05	45	3	6.40	3.40	9.07±0.12
13	0.10	0.00	60	3	0.00	0.00	0.00
17	0.08	0.03	45	3	0.00	0.00	0.00

Conclusion

Nanostructure polypyrrole (50 to 150 nm) and polypyrrole-zinc oxide nanocomposite (30 to 120 nm) were synthesized on the cellulose film by chemical means at ambient temperature. A central composite design was used to investigate the effect of pyrrole concentration and zinc oxide concentration as well as the time of composite synthesis on the antioxidant properties and electrical conductivity of the films. Antimicrobial, antifungal and mechanical properties of the films were also studied. Polypyrrole synthesis and polymer synthesis time had a positive effect on the antimicrobial and antifungal properties of the films. Increasing the concentration of pyrrole and its synthesis time, the antimicrobial and antifungal properties of the films increased, but ZnO nanoparticles were effective only on the antifungal property. By adding polypyrrole, the electrical resistance decreased. In general, the results of this study showed that polypyrrole and zinc oxide have a high potential to be used as an antioxidant and antimicrobial and fungal agents in food storage. Considering the electrical conductivity of polypyrrole and considering this fact that the electrical conductivity of the film changes under different oxidation conditions, these films can be used in intelligent packaging of food products.

References

Emamifar, A., Kadivar, M., Shahedi, M., & Soleimanian-Zad, S. (2011). Effect of nanocomposite packaging containing Ag and ZnO on inactivation of Lactobacillus plantarum in orange juice. *Food Control*, *22*(3-4), 408-413. doi:https://doi.org/10.1016/j.foodcont.2010.09.011

Esa, F., Tasirin, S. M., & Rahman, N. A. (2014). Overview of bacterial cellulose production and application. *Agriculture and Agricultural Science Procedia*, *2*, 113-119. doi:https://doi.org/10.1016/j.aaspro.2014.11.017

Nawaz, H. R., Solangi, B. A., Zehra, B., & Nadeem, U. (2011). Preparation of nano zinc oxide and its application in leather as a retanning and antibacterial agent. *Canadian Journal on Scientific and Industrial Research*, *2*(4), 164-170.

Siracusa, V., Rocculi, P., Romani, S., & Dalla Rosa, M. (2008). Biodegradable polymers for food packaging: a review. *Trends in Food Science & Technology*, *19*(12), 634-643. doi:https://doi.org/10.1016/j.tifs.2008.07.003