6th International Electronic Conference on Medicinal Chemistry
1-30 November 2020
sciforum.net/conference/ECMC2020
sponsored by pharmaceuticals

Antimicrobial properties of PVP-encapsulated Aloe Vera -iodine hybrids

Zehra Edis [1,*], Samir Haj Bloukh [2], Hamid Abu Sara [2]

[1]College of Pharmacy and Health Science, Department of Pharmaceutical Sciences, Ajman University, PO Box 346, Ajman, United Arab Emirates
[2]College of Pharmacy and Health Science, Department of Clinical Sciences, Ajman University, PO Box 346, Ajman, United Arab Emirates

- Corresponding author: z.edis@ajman.ac.ae

Antimicrobial properties of PVP-encapsulated Aloe Vera - iodine hybrids

جامعة عجمان
AJMAN UNIVERSITY

Abstract:
Resistance of pathogens towards commonly used drugs endangers the survival of mankind. Nosocomial infections, increasing treatment duration and costs are already recorded throughout the world. New classes of antimicrobial agents based on natural plant extracts offer valuable solutions due to their naturally evolved synergistic mechanisms in the fight against microorganisms. *Aloe Vera Barbadensis* Miller (AV) is used since centuries against ailments due to its antimicrobial, anti-inflammatory properties. Iodine is well known and used traditionally as antimicrobial agent, although it has the side effects of skin discoloration and irritation. Another drawback of iodine is the uncontrolled and fast iodine release resulting in short activity. We combined AV gel extract with iodine through a cost-effective and easy one-pot synthesis with polyvinylpyrrolidone (PVP) as encapsulating and stabilizing agent. Smart triiodides with halogen bonding were formed within the PVP matrix by adding iodine (I_2) and sodium iodide (NaI) to the AV-PVP hybrid. Fourier transform infrared spectroscopy (FT-IR) and Ultraviolet-visible spectroscopy (UV-Vis) verified the composition of our compounds. The antimicrobial testing by disc diffusion method against a 10 reference microbial strains showed excellent to intermediate antimicrobial activity. The triiodide moieties within AV-PVP induced controlled release of iodine and resulted in enhanced microbial inhibition enabling the use as wound care product and skin disinfectants.
Keywords: *Aloe vera*; iodine; halogen bonding; antibiotic resistance; antimicrobial resistance; biomaterials; antimicrobial activity; synergism; nosocomial infections

Introduction

Antibiotic resistance is a danger for the existence of mankind. Infections caused by multi-drug-resistant microorganisms lead to increasing mortality, morbidity, long-term treatment and economic burden in the United States, European Union and worldwide. The World Health Organization (WHO) considers antibiotic resistance as a major threat for human existence. Resistance has emerged through the uncontrolled use of available antibiotics worldwide and missing efforts to replace them with new generations of drugs.

Delays in the healing process rates, prolonged treatment durations, rising morbidity, mortality and economic burden on the health care system are markers of the urgent need for new antimicrobial agents. The ESKAPE pathogens (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter spp.*, and *Escherichia coli*) belong to the most resistant species. Methicillin-resistant *Staphylococcus aureus* (MRSA) is responsible for causing the highest infection-associated deaths in the United States of America. Nosocomial infections are part of the problem in the treatment of severely ill, immunocompromised patients with comorbidities. The contamination of health care and public settings with microorganisms cause secondary infections and severe complications can be tackled by the use of antimicrobial agents.

Introduction

Iodine (I_2) is an important microbicide and has many applications in the medical field, as commercial disinfectants, and against biohazards. Complexed compounds with iodine are interesting materials and can be designed in the form of different polyiodides. Halogen bonding within the polyiodide units are “smart” reservoirs of molecular iodine. These reservoirs can be utilized against pathogenic microorganisms through the controlled release of iodine from the complexed halogen-bonded polyiodides.

Aloe barbadensis Miller (AV) is a well-known, low-cost, easy-to-cultivate plant, which even grows in arid regions. The gel inside the leaves of AV consists of more than 98% water and 1–2% bioactive compounds. More than 75 bioactive substances are available in AV, including acemannan, aloin, aloe-emodin, aloesin, aloe-mannan, flavonoids, sterols, amino acids, vitamins, enzymes, and minerals. AV components have promising antimicrobial properties, many pharmacological applications and are used against many diseases since centuries in many cultures.

Introduction

Polyiodides in *Aloe Vera*-biosynthesized composites may have the potential for developing new generation antibiotics and antimicrobials. These materials may disable microbial defense mechanisms, which usually lead to resistance.

In this work, we encapsulated freshly extracted AV gel with polyvinylpyrrolidone (PVP) and incorporated iodine (I_2), as well as sodium iodide (NaI) into the polymer matrix. The resulting biomaterial was tested against 10 different microorganism by disc-dilution methods and compared to common antibiotics.

Further investigations are ongoing with additional silver nanoparticles (AgNP). Preliminary results show increase of the antimicrobial properties of the resulting AV-AgNp-PVP-I_2 biocomposites.

Results and discussion

The samples were analyzed by SEM/EDS, x-ray diffraction (XRD), UV-vis, and FT-IR. These methods confirmed the composition of AV-PVP-I_2 and AV-PVP-I_2-NaI. All the complexes are stable and stay homogenous for when stored in the fridge. Further investigations for AV-AgNP-PVP-I_2 and AV-AgNP-PVP-I_2-NaI are going on and give promising preliminary results.

The bioactive compounds AV-PVP-I_2 and AV-PVP-I_2-NaI illustrated evidently vigorous antifungal properties (Figure 1). AV-PVP-I_2 inhibited *C. albicans WDCM 00054* more than AV-PVP-I_2-NaI (Figure 1g,h). Gram-negative and Gram-positive pathogens are also inhibited by both complexes. *P. mirabilis ATCC 29906* is the only resistant microorganism against our two compounds. The antimicrobial tests for AV-PVP-I_2 showed larger ZOI compared to AV-PVP-I_2-NaI (Figure 1). Both compounds exhibited high inhibition zones against *S. aureus ATCC 25923* and the spore forming bacteria *B. subtilis WDCM 00003* at concentrations of 50 µg/mL (Figure 1).

جامعة عجمان
AJMAN UNIVERSITY

Results and discussion

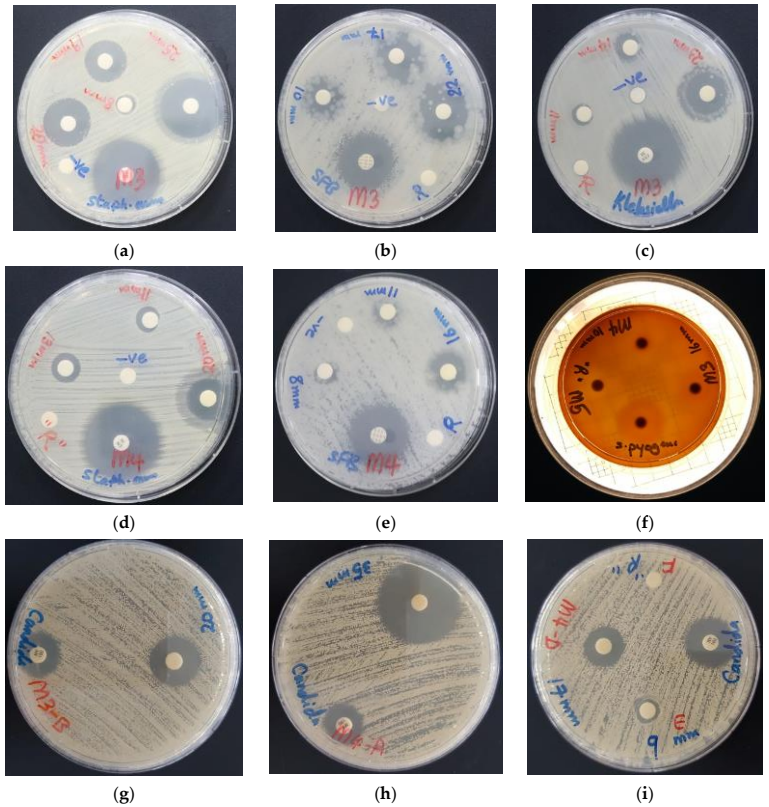

Figure 1. Antimicrobial disc dilution assay of biocomplexes with positive controls (antibiotic). From left to right: AV-PVP-I_2 against (**a**) *S. aureus ATCC 25923*; (**b**) *P. aeruginosa WDCM 00026;* (**c**) *B. subtilis WDCM 00003*. From (**d**,**e**): AV-PVP-I_2-NaI against (**d**) *S. aureus ATCC 25932;* (**e**) *B. subtilis WDCM 00003*; (**f**) AV-PVP-I_2, AV-PVP-NaI and AV-PVP-NaI against *S. pyogenes ATCC 19615*. From (g–i): Susceptibility of *C. albicans WDCM 00054* towards (**g**) AV-PVP-I_2 (25 μg/mL); (**h**) AV-PVP-I_2-NaI (50 μg/mL); (**i**) AV-PVP- I_2-NaI (D = 6 μg/mL, E = 3 μg/mL, F = 1.5 μg/mL).

Results and discussion

The UV-vis spectra of AV, AV-PVP-I_2 and AV-PVP-I_2-NaI, and AV-PVP-NaI are shown in Figure 2.

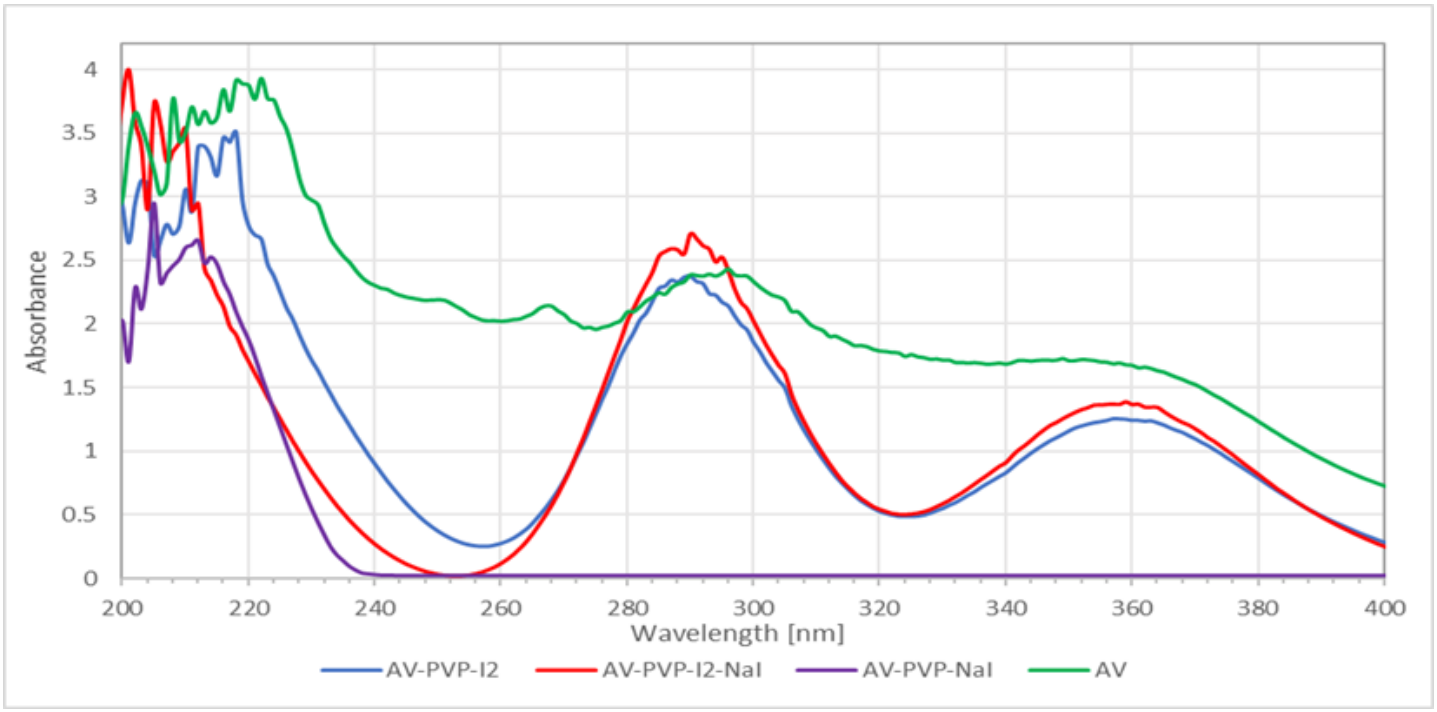

Figure 2. Ultraviolet-visible (UV-vis) spectrometric analysis of the samples. From up to down: (**a**) AV-PVP-I_2 and AV-PVP-I_2-NaI; (**b**) AV and AV-PVP-NaI; (**c**) AV, AV-PVP-I_2 and AV-PVP-I_2-NaI, and AV-PVP-NaI.

Results and discussion

The absorption bands of iodine and the triiodide ion in AV-PVP-I_2 and AV-PVP-I_2-NaI are observed at 290 and 359 nm (Figure 2). These bands are not available in the UV-vis-spectrum of AV-PVP-NaI (Figure 2). AV absorptions are in the regions from 200–235 nm in the UV-vis spectra of all samples as reported by previous groups (Figure 2). Our AV species is confirmed by the FT-IR spectrum as *Aloe barbadensis* Miller, and is in agreement with previously reported works (Figure 2). The presence of PVP is verified by the absorption signal around 220 nm, which is attributed in the literature to originate from the carbonyl groups of polyvinylpyrrolidone. The UV-vis spectra affirm the composition of our biocomplex compounds by the presence of all absorption signals related to AV, PVP and iodine.

Results and discussion

The FT-IR spectra of AV-PVP-I_2 and AV-PVP-I_2-Na are both similar (Figure 3). FT-IR analysis of AV-PVP-I_2 and AV-PVP-I_2-Na confirmed the composition of the samples. Figure 3 shows the FT-IR spectra of AV-PVP-I_2 and AV-PVP-I_2-Na.

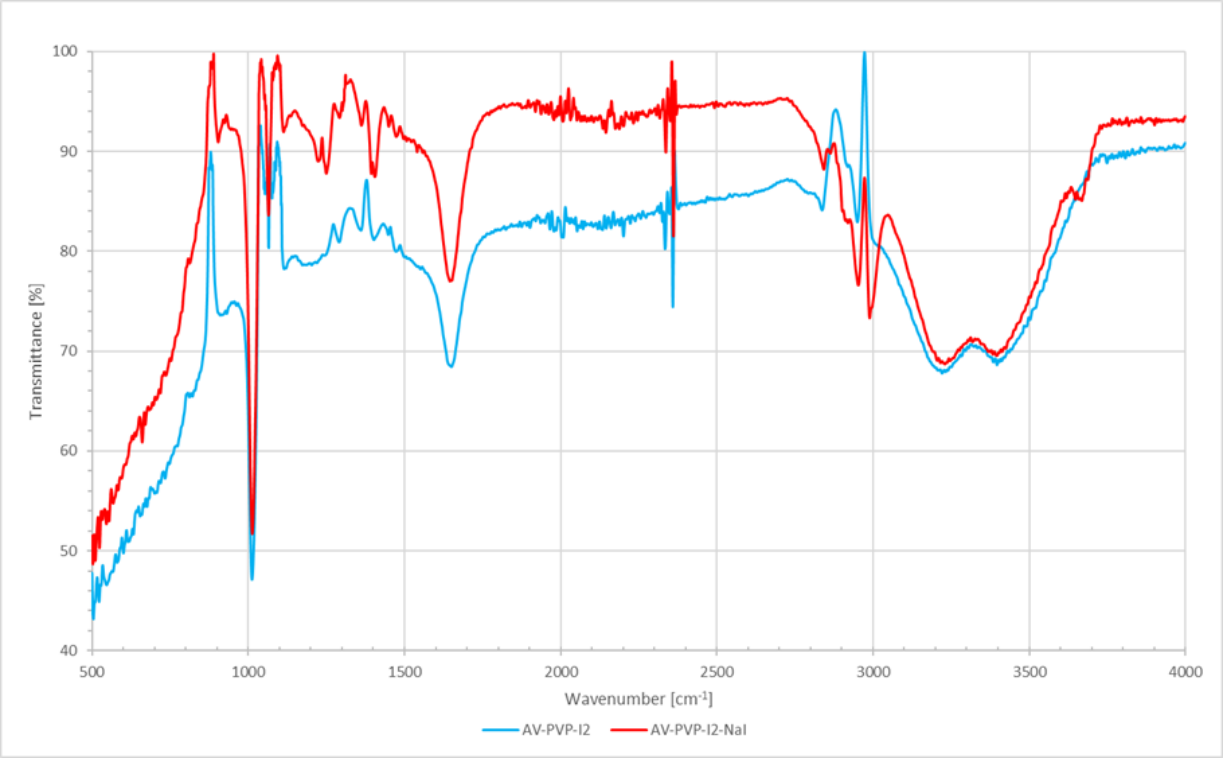

Figure 3. Fourier-transform-infrared (FT-IR) spectrometric analysis of AV-PVP-I_2 and AV-PVP-I_2-Na.

Results and discussion

The FT-IR spectra of AV-PVP-I_2 and AV-PVP-I_2-Na are both similar (Figure 3). The broad band around 3000 to 3600 cm^{-1} is due to OH (alcohol group) and NH (amide group) stretching vibrations (Figure 3). These broad bands with broad bands around 3220 and 3397 cm^{-1} originate from AV and PVP. Asymmetric and symmetric stretching vibrations of methylene (CH_2) are available for AV-PVP-I_2 at 2952, 2919 and 2837 cm^{-1} and for AV-PVP-I_2-Na at 2952, 2920, 2843, and 2864 cm^{-1}, respectively (Figure 3). The asymmetric COO-stretching vibrations are present at 1650 and 1648 cm^{-1} for AV-PVP-I_2 and AV-PVP-I_2-Na, respectively (Figure 3). Symmetric COO-stretching of the carboxylate groups appear 1403 cm^{-1} for AV-PVP-I_2 and at 1406 and 1395 cm^{-1} for AV-PVP-I_2-Na (Figure 3).

Conclusions

Antibiotic resistance is a dangerous phenomenon and is already causing an economic burden on the health care system with increased treatment duration, morbidity and mortality. These problems arise through multidrug resistant microbial strains, biofilm formation, especially in hospital settings and nosocomial infections. Increasing burden on the health care system, treatment failures, prolonged treatment duration, morbidity and mortality are linked to the resistance of pathogens towards some existing drugs and antimicrobial agents. New generations of low-cost plant-iodine-based, biosynthesized agents with high effectiveness and abundant sources are needed. Our biocomplexes AV-PVP-I_2 and AV-PVP-I_2-NaI proved to have excellent antifungal properties against *C. albicans WDCM 00054*. Strong inhibitory effects at concentrations of 50 µg/mL against *S. aureus ATCC 25923* were revealed by disc diffusion assay.

Conclusions

Bacillus subtilis WDCM 00003, *E. coli WDCM 00013*, *P. aeruginosa WDCM 00026*, and *K. pneumoniae WDCM 00097* bacterial reference strains were inhibited intermediately. Our biocompounds with PVP encapsulated *aloe vera barbadensis* Miller, and iodine showed higher antimicrobial activity than our previously investigated bio-nanocomposites with silver nanoparticles, povidone iodine and *cinnamomum zeylanicum* extracts, at the same concentration against the same reference strains *in-vitro*.

Further in vivo investigations on our new, cost-effective, non-toxic antimicrobial agents AV-PVP-I_2 and AV-PVP-I_2-NaI are needed to undermine the expected antimicrobial action with added AgNP in form of AV-AgNP-PVP-I_2 and AV-AgNP-PVP-I_2-NaI nano-biocomplexes.

Their facile, rapid and low-cost profile opens up a spectrum of potential uses as disinfectants, sanitizers, coating materials in personal protective equipment (PPE), health care settings, public spaces and indoor environments.

Acknowledgements

The authors gratefully acknowledge Ajman University and the Deanship of Research and Graduate studies for supporting this research project under the reference number 2020-IRG-PH-10.