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A Scoping Review on Antibacterial Effect of Modification of Silver nanoparticles with Zeolite

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Abstract
Due to ongoing rise in microbial resistance with antibiotic, silver nanoparticles (AgNPs) has gained a lot of attention among the researches as antibacterial agent. Therefore, this paper attempts to identify fruit peel extract as reducing agent/stabilizing agent for biosynthesis of AgNPs, incorporation of AgNPs with zeolite (Zeo-AgNPs) to allow gradual released of AgNPs and its characterization. This paper also includes the assessment of AgNPs and Zeo -AgNPs for its antibacterial effect and mechanism of action. A comprehensive study was done by using several databases such as PubMed, Web of Science and Science Directs with specific keyword. After screening the tittle, abstract and full text review, 29 studies were selected to discuss about the antibacterial effect of biosynthesized AgNPs and Zeo-AgNPs. We also discuss about optimization conditions, physiochemical properties of AgNPs and Zeo-AgNPs followed with methods for their characterization including UV-vis spectroscopy (UV-vis), Fourier transform infrared spectroscopy (FTIR), X-ray diffractometry (XRD), Energy-dispersive X-ray spectroscopy (EDX), Scanning electron microscopy (SEM) and Transmission electron microscope (TEM). In summary, this study could pave the way for development of AgNPs and Zeo-AgNPs with desired properties for effective treatment of bacterial infections in humans.
Keywords Biosynthesis; Silver nanoparticles; Fruit Peel Waste; Zeolite; scoping review; Antibacterial

Introduction

Silver nanoparticles (AgNPs) is a cluster of silver atoms that varies in size from 1 to 100 nm with unique properties including distinctive electrical, optical and biological properties. AgNPs have been extensively used in many fields especially biomedical field such as wound dressing agent and medical device coatings due to antimicrobial properties that they display. In order to meet the necessity of AgNPs for biomedical application, varies techniques are studied and adopted for synthesis.

Conventional method have successfully fabricate AgNPs but the methods seem to cause environmental defect, technically laborious and economically expensive (Zhang et al., 2016). Because of this, biological method by using fruit peel extract (FPE) have emerged as viable alternative synthesis of AgNPs. The phytochemical components inside FPE can directly reduce silver ions (Ag^+) to metallic silver, combine them into clusters and later coats on the surface of AgNPss to stabilize them (Phongtongpasuk et al., 2017). However, AgNPs in colloidal form have stability issues such as poor dispersion, rapid release and low storage stability which limits its application (Hasanzadeh et al., 2020). Therefore, one alternative approach to overcome this problem by incorporation of AgNPs with a carrier system to produce nanocomposite. Zeolite has been considered as an organic reservoir for AgNPs due to high ion-exchange capability, lattice stability, high thermal stability, chemical resistance and cost effective which suitable for these antibacterial application (Shameli et al., 2011) (Milenkovic et al., 2017). It serves as protection to AgNPs by providing a rigid and stable structure and also prevent from aggregation, hence, Ag^+ to can be slowly released and last for longer time (Hasanzadeh et al., 2020).

In this scoping review, we are interested to summarize the capability of zeolite to incorporate with biosynthesized AgNPs as antibacterial agent. There are numerous reviews about antibacterial effect of AgNPs but lacking of comprehensive review on biosynthesized Zeo-AgNPs for antibacterial effect. Therefore, this scoping review attempts to fill the void. This review includes biosynthesis of AgNPs from the reduction of silver nitrate solution ($AgNO_3$) by using FPE as reducing and stabilizing agent, and optimization of biosynthesis method to produce AgNPs. The characterization of biosynthesized AgNPs and Zeo-AgNPs are also included to confirm the presence of AgNPs inside the cavities of zeolite framework. This review also emphasizes mechanism of antibacterial activity of AgNPs and a summary of antibacterial activity exhibited by both AgNPs and Zeo-AgNPs, including its limitation and challenges.

Materials and Methods

A scoping review was conducted following the recommendation from the PRISMA statements which conducted by using PubMed, Web of Science and Science Directs. The search strategies used to collect data from each database described as below: (1) PubMed: ((((biosynthesized silver nanoparticles)) OR (natural zeolite)) OR (clinoptilolite)) AND (antibacterial)) NOT (review)). (2) Web of science: ((((ALL=biosynthesized silver nanoparticles)) OR ALL= (natural zeolite)) OR ALL=(clinoptilolite)) AND ALL=(antibacterial)) NOT ALL=(review). (3) Science Direct: (biosynthesized silver nanoparticles AND peel extract AND antibacterial NOT review). Titles and abstracts obtained from the search strategies were screened for eligibility, followed by full-text reading and data extraction of relevant records. The results were cross-checked and any discrepancies were resolved by discussion between reviewer and supervisor when there were differences.

The eligibility criteria included exclusion and inclusion criteria to select the relevant data for this scoping review. The inclusion criteria were described as follow : (1) All English languages full-text articles that comprised research article with laboratory studies ; (2) Studies that examined the antibacterial application of biosynthesized silver nanoparticles (AgNPs) and silver nanoparticles incorporated with zeolite (Zeo-AgNPs) in all fields (water disinfection, foodborne pathogen, wound dressing and remediation soil contamination); (3) Studies that related with biosynthesized AgNPs which using only FPE as stabilizing agent; (4) Studies that included characterization result for biosynthesized AgNPs and Zeo-AgNPs ; (5) Studied that included antibacterial test for AgNPs and Zeo-AgNPs.Exclusion criteria were as follows: (1) Studies that conducted before 2011 was excluded; (2) Studies that used other metallic nanoparticles (Zinc, Copper and Barium) except silver ion which loaded into zeolite; (3) Studies that incorporated Zeo-AgNPs with another composite (synthetic polymer, silicone, gelatin, chitosan and graphene oxide); (4) Studies that conducted with conference abstracts, insufficient data and lack of primary data. All the collected data were registered on a worksheet with the aid of Microsoft Excel.

Specific information comprised of the type of FPE used as a stabilizing agent and optimization parameter (temperature, pH, concentration of silver salt, volume of FPE and time for incubation) to produce high yield AgNPs have been collected from the selected publication. Besides, several spectroscopic and microscopic techniques used for the characterization of biosynthesized AgNPs and Zeo-AgNPs such as UV-vis spectroscopy (UV-vis), Fourier transform infrared spectroscopy (FTIR), X-ray diffractometry (XRD), Energy-dispersive X-ray spectroscopy (EDX), Scanning electron microscopy (SEM) and Transmission electron microscope (TEM) were included to validate the formation of AgNPs and Zeo-AgNPs summarized in this scoping review. Other than that, the evaluation of antibacterial activity from biosynthesized AgNPs and Zeo-AgNPs against different kinds of microbes through a variety of techniques were also collected.

The review includes evaluation of antibacterial activity of AgNPs and Zeo-AgNPs against either gram-positive and gram-negative bacteria.

Results and Discussion

In the initial research, 1028 articles were found in scientific databases through manual research and after removing duplicates, 777 records were selected for tittles and abstract screening. Based on the inclusion and exclusion criteria, 287 records were considered eligible for full-text screening. Finally, reviewing the full texts of the remaining studies indicated that 29 studies were eligible for an in-depth examination of the content. These studies ranged in publication date from year of 2011- 2021.

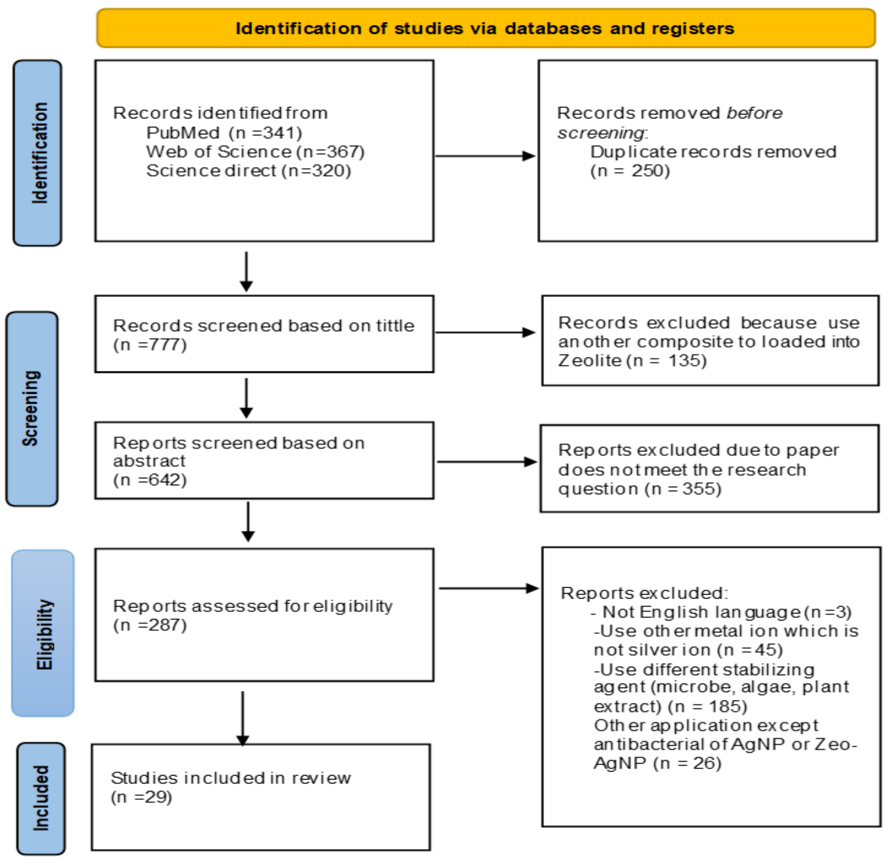

Figure 1 Flow chart depicting selection criteria

For this review, fifteen journal out of 1028 research articles were selected as they utilized FPE as bioreduction and capping/stabilization of AgNPss. Each FPE contain different amounts of phytochemicals which responsible for reduction of silver ions (Ag^{+}) into silver atoms (Ag^{0}). Therefore, optimization of the synthesis method is required to control shape, size and distribution, which can be affected by the variety and quantity of the phytochemical compound in AgNPs. To broaden the application of AgNPs, zeolites was selected as reservoir material to prevent the aggregation, increase AgNPs surface area, as well as its antibacterial efficiency. Zeolites that are known as hydrated crystalline aluminosilicates, contained exchangeable cations such as $Na^{+}, K^{+} Mg^{2+}$ and Ca^{2+} to stabilize the negative charge in the Al–O–Si network. Zeolite undergo ion-exchange process with AgNPs to load Ag^+ in the zeolite framework. All information related with Zeo-AgNPs were obtained from another fourteen research articles. The formation of AgNPs and Zeo-AgNPs that were validated using UV-Vis, FTIR, SEM, EDX, XRD, TEM and SEM were describe in the review. Selected publications also reported different types of microbes used for testing with AgNPs and Zeo-AgNPs, to determine their efficiency as antibacterial agents. Details on the study exclusions were elaborated in Figure 1.

FPE contained high amounts of bioactive compounds and secondary metabolites to be extracted as reducing and stabilizing agents for the synthesis of AgNPs. Saratale et al., (2018) established that grape pomace are rich with wide range of active ingredient, namely phenolic acids, flavonoids, anthocyanins, resveratrol, and proanthocyanidins which involved with formation of AgNPs. In another study by Sun et al., (2021) it was also mentioned that bioactive compound from kiwi peels consist of phenolic compounds, polysaccharides and cellulose can be used as biological reducing agents. Based on the selected publications for this scoping review, 65% mentioned that among the bioactive compounds, phenolic exhibits a strong antioxidant activity and bio-reducing ability. Therefore, we can conclude that among all phytochemical compound which can be found in FPE, phenol play important role to reduce and stabilize AgNPs. The hydroxyl and carboxyl groups attached on the phenolic compounds have the ability to bind on silver (Ag) to convert Ag^+ to silver nanoparticles AgNPs. In addition, these functional groups also formed biomolecule layer surround the AgNPs to prevents them aggregate with each other, thus stabilize AgNPs structure.

It was also noted that different FPE can contain different amounts of phenol content, which are usually measured through Folin-Ciocalteu (FC) method (Vidhu & Philip, 2014) . This method showed the reaction solution of FPE with FC reagent formed of bleu colored chromogen that indicate the reduction of electron in phenolic compound as it reacts with phosphomolybdic or phosphotungstic acid in the FC reagent. This colour changed can be detected using visible spectra at 760nm (Ford et al., 2019). This analysis is important to show the higher content of phenolic existing in FPE helped to support in the fast reduction of Ag ions and better stabilization of AgNPs (Saratale, Saratale, Kim, Kim, & Shin, 2020). Table 4.1 showed total phenolic content from various sources of FPE.

Table 1 : Total phenol content from different FPE

FPE	**Total phenol content (mg of GAE/g)**
Vitis vinifera (grape pomace)	32.38± 2.85
Hylocereus undatus (dragon fruit)	4.21±0.036
Dimocarpus longan (longan)	26.96±0.0016

Characterization studies of prepared nanomaterials is usually conducted to confirm the shape, size distribution, surface area, solubility, elemental composition and aggregation of the AgNPs. Various analytical techniques have been introduced to evaluate the biosynthesized AgNPs and Zeo-AgNPs such as ultraviolet visible spectroscopy (UV-Vis), X-ray diffractometry (XRD), Energy-dispersive X-ray spectroscopy (EDX) Fourier transform infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

UV-vis spectroscopy is the main technique for the primary characterization of biosynthesized AgNPs in aqueous solution, as well as monitoring its stability. AgNPs have free electrons, which give rise to surface plasma resonance (SPR) due to collective oscillation of electron between AgNPss in response to light wave (Kaviya et al., 2011). The appearances of the peaks show the characteristics of surface plasmon resonance of AgNPs (Anandalakshmi et al., 2016) .

The studies showed that characteristic peak of AgNPs prepared using extracts from fruit peels commonly detected in the range of 405-440nm. Sun et al. for instance who performed biosynthesis of AgNPs using kiwi fruit discover SPR peak for this AgNPs at 459nm almost similar as SPR peak of AgNPs from dragon fruit which at 457nm. However, we can also observe that several SPR peak of biosynthesized AgNPs appear out from the range for example AgNPss by using watermelon rind (485nm), pomegranate peel (378nnm) and lychee peel (402nm) and pineapple peel (485nm). The different result absorption peak of UV-vis spectrum influences by the size of AgNPs and bioactive compound in FPE. Basically, peaks at the longer wavelength indicate an increase in size particle whereas, smaller size NP represent by peak at shorter wavelength (Patra et al., 2016). The various quantities of bioactive compound in FPE may have affected the nucleation and growth of AgNPs which influenced the size of biosynthesized AgNPs (Chutrakulwong, Thamaphat, & Limsuwan, 2020). Therefore, we can conclude that AgNPs prepared using watermelon rind and pineapple peel have larger size due to small amount of phytochemical compound compare to AgNPs by using lychee peel and pomegranate peel which contain high amount of bioactive compound to produced small size AgNPs.

Due to different amount of bioactive compound in every kind of FPE, optimizing reaction condition is required to produce AgNPs. Several factors were identified in optimizing synthesis method for AgNPs, especially in controlling its size, stability and yields of AgNPs (Ibrahim, 2015). It should be noted that the concentration of $AgNO_3$, volume of FPE , pH value, time of incubation, temperature have been suggested as as several parameter that can enhance the optimizing conditions for biosynthesized AgNPs (Mittal, Chisti, & Banerjee, 2013)

In order to identify functional group in FPE that responsible for the stabilization of AgNPs, FTIR analysis was performed commonly in the spectral range of 4000–400 cm^{-1}.Multiple studies revealed that functional groups of -OH, -COOH and C=O may involve with the reduction and stabilization of biosynthesized AgNPs (Kokila et al., 2016) (Phongtongpasuk et al., 2017) (Pugazhenthiran et al., 2021). The finding can be proved by Phongtongpasuk et al., (2016) which observed the shifting of FTIR spectral between dragon fruit peel extract and biosynthesized AgNPs. The FTIR peaks showed a shift in the following peaks 3420-3433 and 1103-1022 cm^{-1} which is related to OH stretching of phenol or carboxylic acids and C-OH stretching of carboxylic acid, respectively. Besides, the functional group of C=O stretching of carbonyl group which present in dragon peel extract at 1741 cm^{-1} was absent in from FTIR spectral of biosynthesized AgNPs. This clearly indicated C=O together with -OH and COOH groups involve in reduction and stabilization to form AgNPs. These functional groups (-OH, -COOH and C=O) may belong to biomolecule that mainly contain in dragon peel extract which is phenolic compound.

FTIR also can be used to characterized Zeo-AgNPs to determine the chemical structure and to indicate the secondary building units which were found in the zeolite structure. Shameli et al., (2011) conducted a study to characterize Zeo-AgNPs by using FTIR and discover several peaks that indicate to chemical composition of zeolite. The author reported the peaks at 3353 cm^{-1} due to O-H stretching, 1646 cm^{-1} indicated to H-O-H bending and 969 cm^{-1} indicate with Si-O stretching. Si-O-Si vibration bending also can be found from an intense band at 546-461 cm^{-1}. These peaks clearly revealed chemical composition of zeolite that made of silicon, aluminium and oxygen that form a framework with cavities and channels inside where cations, water and/or small molecules may reside. The interaction between AgNPs and zeolite can be discovered at peak of 3353 cm^{-1} indicated to the OH groups belong to H_2O from the zeolite structure and the partial positive charge on the surface of Ag NPs which interact through van der Waals interaction. Based on these studies, FTIR analysis is used to determine the chemical structure and chemical interaction of Zeo-AgNPs.

XRD analysis determine the elemental composition in AgNPs which can be achieved with nanochomatic Cu K α radiation (λ=1.540609 A) radiation.In this scoping review, most of the authors discovered three diffraction peaks of (111), (200) and (220) which represent the face centred cubic of silver (Kaviya et al., 2011) (Perveen et al., 2018) (Devanesan et al., 2018)(Das et al., 2019). Devanesan et al.,

(2018) proposed a study about XRD analysis on biosynthesized AgNPs using pomegranate peel as reducing agent. The study reported several peaks are observed at 2 from, 0 to 90 which can be indexed to 111, 200, 220, and 311 plane of a faced cube with central Ag ion. The result from XRD spectrum suggest that the sample of biosynthesized AgNPs formed into crystalline structure.

Moreover, multiple studies have shown that XRD is used to identify crystallographic structure of Zeo-AgNPs and to confirm the success production of Zeo-AgNPs. A study conducted using Zeolite Y incorporated with biosynthesized AgNPs discovered several prominent peaks at 27.6°, 32.05°, 46.05°, 54.6°, 57.3°,67.4°, 74.5° and 76.6° with plane of 111, 200, 220, 311, 222, 400, 311 and 420 reflections owing to the silver chloride (AgCl), precursor for Ag in this study (Selvamuthumari, Meenakshi, Ganesan, Nagaraj, & Pandian, 2016).Result from this study confirm that AgNPs loaded within zeolite.

The elemental composition of synthesized AgNPss was determined by EDX technique. In this scoping review, EDX is carried out in order to identify the presence of Ag element in the nanocomposite.

Multiple studies established that the distinct peak at 2.8-3.2 keV on the EDX is attributed by the presence of Ag which can confirmed the formation of AgNPs (Phongtongpasuk et al., 2017) (Sun et al., 2021) (Ibrahim, 2015). A study of EDX analysis conducted by utilize pineapple peel extract as stabilizing agent to form biosynthesized AgNPs (Das et al., 2019). The result from EDX study showed formation of Ag signal at 3Kev which indicate the formation of AgNPs. Similar result also obtained from AgNPs prepared using banana peel (Ibrahim, 2015) and citrus peel (Kaviya et al., 2011). In addition, EDX also provide information about atomic weight percentage in the sample. From the selected studies, we can conclude that biosynthesized AgNPs contain approximately 50-70% weight percentage of Ag element. Devanesan et al., (2018) conduct EDX analysis on biosynthesized AgNPs prepared using pomegranate peel extract as capping agent, estimated that the NP sample consisted of 70% Ag weight. Not only Ag element can be found in biosynthesized AgNPs, but the presence of some other element such as Cl, O, N, Pt and S also can be found. These elements in which originated from the biomolecule that acts as capping agent and bound to the exterior of the AgNPs.

EDX analysis also can be conducted to Zeo-AgNPs in order to confirm the presence of AgNPs in zeolite matrix with present of Ag peak between 3-4.5KeV. In addition, EDX analysis also can be used to determine chemical composition of Zeo-AgNPs. Gemishev et al., (2016) discovered the presence of basic element in zeolite such as O (47.69%), Si (32.52%), Al (7.42%), K (2.67%), and Ca (1.64%) was found in the sample based of peak arose from EDX analysis. Similar elements was found from EDX analysis of zeolite Y loaded with AgNPs (Salim, Ahmad, & Nik, 2016). Author reported that peaks around 1.49, 1.65, 2.38, 2.55, 2.86, 3.22, 4.54, 5.52, 6.47, and 7.42 keV corresponding to element C, O, Na, Al and Si from the EDX analysis. The results from EDX analysis indicated the main elements in zeolite Y were silicon and aluminium, which have tetrahedral links with oxygen, and sodium ions, which are present in the zeolite frame- work and on the zeolite surface to stabilize the negative charges from the aluminium. In addition, peak at 3.1, 3.3, and 3.4 keV also found in EDX analysis which associated to silver elements to confirmed the presence of elemental of AgNPss in NaY zeolite matrix. Therefore, this scoping review concluded that EDX analysis is used by most of authors to provide them with information about elements which is present in AgNPs and Zeo-AgNPs.

SEM and TEM are high-resolution microscopy technique which capable to provide information about the size distribution and surface morphology of biosynthesized AgNPs and Zeo-AgNPs. In this scoping review, SEM and TEM analysis was also conducted in a number of studies to provide information about the morphology and size distribution for AgNPs and Zeo-AgNPs. Based on the result from selected publications, SEM and TEM analysis on biosynthesized AgNPs discovered the shape of AgNPs was spherical in nature and the particle size distribution of AgNPs was measured between 20-260 nm. According to Devanesan et al (2018), it is very crucial to obtain the information of size and shape of AgNPs because the size of AgNPs which is less 100nm play important role in drug delivery system and antibacterial application. The author also reported that nanoparticles with 100nm size exhibit 2.5-fold greater uptake compared to 1µm particles. For evaluation of characterization of Zeo-AgNPs by using SEM analysis, efficiency of zeolite as carrier for AgNPs could be discovered. A study of structural and morphology was conducted by using AgNPs loaded with Zeolite Y discovered that Zeolite Y has octahedral shape with average size of 1µm while spherical AgNPs size reported as 0.1µm. The result clearly indicated size of AgNPs is considered as small enough to be fitted into the pore of the zeolite. The morphology shown by SEM stipulate that the modification of AgNPs into zeolite does not make any change for shape or size distribution except for the surface roughness is increased between sample zeolite and sample Zeo-AgNPs. The changes for surface roughness on Zeo-AgNPs clearly confirmed the present of AgNPs in the zeolite**.**

This scoping review highlighted *Escherichia coli* (gram negative bacteria) and *Staphylococcus aureus* (gram positive bacterial) are the most commonly studied for microorganism by using several common methodologies which are zone inhibition method (ZOI), minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) to tested the efficiency of AgNPs as antibacterial agent. AgNPs also was more effective against gram negative bacteria relative (GNB) to gram positive bacteria (GPB). Kaviya et al., (2010) proposed a study about antibacterial activity of AgNPs against *Escherichia coli (E. coli), Pseudomonas aeruginosa (P.aeuruginosa)* (GNB) and *Staphylococcus aureus (S. aureus)* (GPB). This study demonstrated that maximum ZOI aligned with *E. coli* (16 mm) and *P.aeuruginosa* (13.4mm) compared *S. aureus* with minimum ZOI value (9.2 mm) bacteria. This result indicated that the difference in antibacterial activity between gram positive bacteria (GPB) and gram-negative bacteria (GNB) due to cell wall composition. GNB cell wall consist of thin peptidoglycan whereas GPB composed of thick peptidoglycan layer, consisting linear polysaccharides chain cross linked by short thick peptidoglycan layer (Pugazhenthiran et al., 2021) .Therefore, a thick peptidoglycan in cell wall of GPB forming more rigid structure and prohibited the entry of AgNPs into the cytoplasm compared to thin peptidoglycan cell of GNB which leading to easy penetration of AgNPs (Kokila et al., 2016)

The specific mechanism of antibacterial activity by AgNPs is ambiguous in microorganism and has not been completely explained. However, several hypotheses have been highlighted in this review based on result from measuring the bacterial cell membrane breakage and cytoplasmic content. Saratale et al., (2020) conducted a study to observe the effect of biosynthesized AgNPs on cellular and molecular level. The release of reducing sugar and proteins concentration of the resultant bacterial supernatant were determined by using DNS procedure and Bradford assay, respectively. The author reported that after bacteria (*E. coli* and *S. aureus*) were treated with AgNPs at different concentration (25-100 µg/mL), a sequential increase in protein and reducing sugar was observed. Result from Saratale et al., (2020) indicated that AgNPs able to destroy the permeability of the bacterial membranes by accumulation of AgNPs in the cell wall which resulting formation of pits and gap in the bacterial cell wall and disturb important function such as osmoregulation, electron transport and respiration eventually leading to cell death(Das et al., 2019).The presence of AgNPs not only causes pores to form in cell membrane but also allowing vital component to escape and resulting in the microorganism's death. In addition, AgNPs can permeate into the cell due to smaller size and can cause further damage to bacterial cell by interacting with DNA, protein and other phosphorus and sulfur containing cell constituents (Ibrahim, 2015). Thus, the measurement of cellular leakage can determine the mechanism lies behind antibacterial activity of biosynthesized AgNPs

Despite AgNPs have a broad spectrum of antimicrobial properties, the extensive and frequent use of AgNPs increases antibacterial resistance. Therefore, AgNPs incorporated with zeolite is necessary to provide gradual release of AgNPs and lower the usage of AgNPs but still maintaining its effectiveness. Even though AgNPs loaded into zeolite, the effectiveness of antibacterial activity of AgNPs still maintained. This can be proved by Flore-Lopez et al., (2012) which loaded AgNPs into natural zeolite known as chabazite (Cbz-AgNPs) and tested its antibacterial activity on *S. epidermidis, S.aureus, S. typhimurium, E.coli, S. Flexne* and *P. aeruginosa.* Result for the study revealed that with 1, 0.1 and 0.001 wt% of Cbz-AgNPs concentration can completely kill *S. epidermidis S. typhimurium, E. coli, S. flexneri* and *P.*

aeruginosa except for *S.aureus* after 42 exposure of treatment. However after 48 hour treatment, the growth of *S.aureus* also is inhibited. *S.aureus* is gram positive bacteria which comprised of thick peptidoglycan that provide rigid structure. Therefore Cbz-AgNPs required more time to inhibit the growth of *S.aureus.* To summarize, this review indicated enough evidence showing the potential of AgNPs loaded into zeolite as antibacterial agent against GPB and GNP.

Conclusion

This review comprehensively addressed the biosynthesis of AgNPs by utilizing different types of fruit peel waste as reducing or capping agent. Besides, stability issue that face by AgNPs also can be solved by the formation of Zeo-AgNPs. Zeolite acts as reservoir material for antibacterial agent as it allows gradual release of AgNPs to microbe and resulting in a sustained antibacterial action on microbe. Moreover, this review emphasizes the important of characterization of AgNPs in order to evaluate the physiochemical properties of AgNPs and to confirmed the presence of AgNPs in zeolite framework. Characterization can be conducted by using a variety of analytical techniques such as UV-vis spectroscopy (UV-Vis), Fourier transform infrared spectroscopy (FTIR), X-ray diffractometry (XRD), Energy-dispersive X-ray spectroscopy (EDX), Scanning electron microscopy (SEM) and Transmission electron microscope (TEM). Furthermore, the review revealed that AgNPs and Zeo-AgNPs have significant antibacterial effect to majority bacteria either GPB or GNP such as *B. subtilis, S.aureus, P. aeruginosa*, *S. typhimurium, S. flexneri E.coli* and *MRSA*. However antibacterial effect of AgNPs and Zeo-AgNPs on GNB is more efficient compare to GPB due to differences in cell wall composition. We hope that this approach of green synthesis will aid researches to utilize the antibacterial effect of Zeo-AgNPs in various kind of application such as to reduce soil contamination triggered by microbe, water purification and utilize as antiseptic. AgNPs are appealing because they are harmless to humans at low concentrations and have antibacterial activity throughout a broad spectrum.

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