EVALUATION OF THE SYNERGISTIC ANTIMICROBIAL ACTIVITIES OF SELENIUM NANOPARTICLES AND ROSEMARY OIL AGAINST ASPERGILLUS FUMIGATU AND KLEBSIELLA PNEUMONIAE RECOVERED FROM RESPIRATORY INFECTION IN CATTLE IN GIZA GOVERNORATE, EGYPT

Atef A. Hassan¹, Dalia Iskander², Noha H. Oraby¹*

Received 10 September 2021, revised 05 May 2022

ABSTRACT: Synergistic and single antimicrobial activities of green synthesized selenium nanoparticles (SeNPs) and rosemary oil were investigated against predominant causes of respiratory diseases in cattle as Aspergillus fumigatus and Klebsiella pneumoniae. The prevalence rates of A. fumigatus were 14.28%, 12%, and 32% in the nasal swab, drinking water, and animal ration, respectively. While, Klebsiella pneumoniae was isolated from examined nasal swabs, water, and rations at the rates of 17.4%, 0%, and 8%, respectively. The minimal inhibitory concentration (MIC) of Se-NPs was 0.4 mg/ml and 0.5 mg/ml against A. fumigatus and Kl. pneumoniae, respectively. On the other hand, the inhibitory concentration of Rosemary against A. fumigatus and Kl. pneumoniae was 0.75 mg/ml and 1.0 mg/ml, respectively. The synergistic therapy of SeNPs dispersed with Rosemary oil reduced the MIC of SeNPs against A. fumigatus and Kl. pneumoniae was 0.1mg/ml and hence can be used as alternatives to their single forms in successful disease therapy. Moreover, these synergisms are essential to overcome the microbial resistance against the traditional antibiotics and decrease the concentrations used of nanoparticles to avoid their toxicity for animals.

Key words: Antimicrobial, Aspergillus fumigatus, Klebsiella pneumoniae, Rosemary oil, Selenium nanoparticles, Synergism.

INTRODUCTION

Nowadays, the worldwide problem of progressive raise in human populations resulted in the increased requirement of animal products, hence urgent significant attention for animal health and their productivity occurred. Hence, the health of large dairy animals as cattle gained intensive studies to improve all health factors related to their successful production (Barkema et al. 2015) The disease condition is considered to be the essential factor affecting their health. The respiratory diseases caused by some fungi in cattle as Aspergillus sp., particularly Aspergillus fumigatus, resulted in mycotic pneumonia, gastroenteritis, and mastitis (Seyedmousavi et al. 2015). As well as, the bacterium of Klebsiella pneumoniae that causes several infections in human and cattle nasal swabs (Cheng et al. 2018). The microbial drug resistance that occurred due to the prolonged wrong use of traditional antibiotics is considered as the most important problem in the control of these infections (Zhang et al. 2021). Therefore, novel antimicrobial agents are required to overcome microbial resistance to conventional antibiotics (Singh et al. 2018). Recently, there is progressive advancement in nanotechnology which enables the synthesis of novel nanosized materials that inhibit microbial growth and suppress their potentials in the occurrence of diseases among veterinary animals (Hassan et al. 2020). In addition, several studies confirmed the antioxidant, antibacterial, and antifungal activities of metals and metal oxide nanoparticles (Hassan et al. 2020, Fouda et al. 2020). In this respect, metal nanoparticles (NPs) particularly selenium NPs have significant and low toxicity (Zheng and Chen 2012).

¹Department of Mycology and Mycotoxins, ²Department of Bacteriology, Animal Health Research Institute (AHRI), Agriculture Research Center (ARC), Dokki, Cairo, Egypt.
*Corresponding author. email: nohaoraby25@gmail.com
However, Geoffrion et al. (2020) used green biosynthesized selenium nanoparticles (SeNPs) and it has antibacterial potential against antibiotic-resistant bacteria *E. coli* and methicillin-resistant *S. aureus*. Also, Menon and Shanmugam (2019) detected that selenium nanoparticles are that produced by the seed of *Mucuna pruriens* gave NPs of nearly 100-120 nm and had half inhibitory concentration (IC50)(60 µg/mL) for inhibition of the cell viability of bacteria at 48h. The green synthesis of SeNPs is cost-effective and environmental friendly that can be utilized in further biomedical applications.

Moreover, SeNPs can be used as drug delivery, additives in food and feed, and detection and treatment of livestock diseases (Husen and Siddiqi 2014). On the other hand, the nano-oil emulsions were successfully used in veterinary medicine as drug delivery and antimicrobial agents (Hassan et al. 2020). Meena et al. (2018) illustrated that the advantages of using the oils. Nanoemulsions have the simplicity, inexpensiveness, stability, versatility and the solubility of lipophilic substances and the ability to protect them from degradation. One of the most useful oils is rosemary oil. It can be used in the processing of food as antioxidants and prevent microbial growth (Barreto et al. 2014). Therefore, the current research articles were undertaken to detect the fungal and bacterial causes of respiratory manifestations in cattle. The most prevalent microbial agents that recovered from the present samples were used for evaluating the effects of SeNPs singly and in combination with Rosemary oil in inhibiting the activities of pathogens. Moreover, the minimum inhibitory concentrations of these agents were measured during all tests in comparison with traditional antibiotics. Additionally, the activities mechanisms of SeNPs and oils and their benefits were fully discussed.

**MATERIALS AND METHODS**

**Samples**

A total of 120 samples (70 nasal swabs and 25 each of water and ration samples) were collected from private cattle farms at Giza Governorate. Approximately 100 gram of each ration sample was aseptically collected, properly seal the sample container to ensure that leakage will not occur during transport. One hundred (100) ml of each water samples was collected from water troughs in sterilized screw capped bottle. Nasal swab was gently inserted the entire soft tip of the swab into one nostril until a bit of resistance was felt and rubbed in a circle around the walls atleast 4 times. One swab was used for both the nostrils and two nasal swabs were taken from each animal. The swab was put into the provided tube and screwed the red cap on tightly. Each sample was divided into two parts; one was subjected to mycological examination, while the second part was subjected to bacteriological examination.

**Antibacterial, antifungal, and other chemicals**

Antibacterial, antifungal, and reagents were obtained from Sigma Chemical Company (USA).

**Selenium nanoparticles and Rosemary oil**

The used Se-NPs were synthesized by green method as per Rai et al (2017) and characterized by the laboratory of ALDRIK Sigma chemical company, USA and it was ...

![SEM picture of Se-NPs](image1.png)

**Fig. 1.** SEM pictures of Se–NPs showed the size and morphology (60 nm) and the UV-VIS absorbance spectra of Se-NPS (60 nm) at 405 nm wavelength.
in amorphous powder form of 60 nm particles size. While, Rosemary oil was purchased in crud form from Al Gomhorya chemical company, Egypt.

**Mycological examination**

The collected samples were prepared, enriched by incubation in Sabouraud dextrose broth at 28°C for 24 hrs and examined for isolation of fungi as a method as (Refai et al. 2012). The samples were cultured on Sabouraud dextrose agar (SDA) and incubated 3-5 days at 25-28 °C. After incubation, the plates were examined macroscopically and microscopically. Identification based on the morphology of the colony, the rate of growth, and microscopic morphology of the isolates according to the description in textbooks dealing with molds (Pitt and Hocking 2009). The fungal isolates were sub-cultured by single spore isolation technique on SDA, CZ, CYA and MEA media. The fungal cultures were separated into groups based on their morphological characteristics including colony size (diameter), texture and surface. The fungal cultures were examined periodically during the incubation period. The culture characteristics and sporulation on different culture media were recorded after 7 days of the incubation period at 28°C. The morphological characteristics of each fungal isolate were determined using the light microscope. The microscopic examination of fungal isolates was described after the fungal colonies were sporulated on the different culture media. For this purpose, small mycelia part from the centre and edge of the growing colony was mounted onto microscope slide using distilled water and covered by a cover slip. The characteristics of vegetative and reproductive structures such as hyphal colour and structures, spore shape, as well as spore size were determined.

**Bacteriological and Serological Examination**

The samples were collected in swabs containing nutrient broth and kept at 37°C for 24 hrs. A loopful from each broth was streaked onto the following media: blood agar, MacConkey’s agar, Edwards agar and incubated aerobically at 37°C for 24-48 hrs. The growing surface colonies (pink, mucoid colonies with 3-4 mm in diameter) were picked up, purified, and re-inoculated into a nutrient broth for further identification which is based on cultural, morphological, and biochemical characteristics (Quinn et al. 2011). Different bacteria were identified routinely using morphological and biochemical tests, followed by different specialized tests, serotyping and antibiotic resistance patterns etc. Water samples were examined according to Oblinger and Koburger (1975).

**Antibiotic sensitivity test**

It was done by disc diffusion method according to (Cruichshank et al. 1975). The results were interpreted according to (NCCLS 2004).

**Green synthesis and Characterization of selenium nanoparticles (Inregole et al. 2010)**

One 100 ml (10-1M) sodium selenosulphate was

| Fungal species               | Type of examined samples | Nasal swabs (n=70) | Water (n=25) | Ration (n=25) |
|-----------------------------|--------------------------|--------------------|--------------|---------------|
|                             |                          | No. | %    | No. | %    | No. | %    |
| Aspergillus fumigatus       |                          | 10  | 14.28| 3   | 12   | 8   | 32   |
| Aspergillus flavus          |                          | 9   | 12.8 | 19  | 76   | 1   | 4    |
| Pencillium sp.              |                          | 2   | 2.8  | 1   | 4    | 0   | 0    |
| Fusarium sp.                |                          | 5   | 7.1  | 1   | 4    | 1   | 4    |
| Mucor sp.                   |                          | 4   | 5    | 1   | 4    | 1   | 4    |
| Candida albicans            |                          | 5   | 7.1  | 1   | 4    | 0   | 0    |
| Geotrichum sp.              |                          | 2   | 2.8  | -   | 0    | 0   | 0    |
| Trichosporum sp.            |                          | 1   | 1.4  | -   | 0    | 0   | 0    |
| Klebsiella pneumoniae       |                          | 12  | 17.14| 0   | 0    | 2   | 8    |
| Klebsiella oxytocha         |                          | 5   | 7.14 | 0   | 0    | 1   | 4    |
| Pseudomonas aeruginosa      |                          | 3   | 4.28 | 4   | 16   | 0   | 0    |
| Staph. aureus               |                          | 2   | 2.85 | 0   | 0    | 1   | 4    |
| Strept. pyogens             |                          | 2   | 2.85 | 0   | 0    | 0   | 0    |
Table 2. Optical density and transmittance of treated A. fumigatus and Kl. pneumoniae by SeNPs and Rosemary oil.

| Concentration of SeNPs/R. mg/ml | A. fumigatus | Kl. pneumoniae |
|---------------------------------|--------------|---------------|
|                                 | OD | T% | OD | T% |
| 0.0                             | 2.00| 0.80 | 0.63 | 23.4 |
| 0.1 SeNPs/0.75 R                | 0.0 | 100 | 0.0 | 100 |
| 0.1 SeNPs/1.0 R                 | 0.0 | 100 | 0.0 | 100 |
| 0.2 SeNPs/0.75 R                | 0.0 | 100 | 0.0 | 100 |
| 0.2 SeNPs/1.0 R                 | 0.0 | 100 | 0.0 | 100 |

* R = Rosemary oil, T = Transmittance.

Evaluation of the synergistic antimicrobial activities of selenium nanoparticles and rosemary oil...

Combination effects of Se-NPs and rosemary oil was performed as above mentioned tests with some modification in addition as follow 0.1 SeNPs/0.75 R, 0.1 SeNPs/1.0 R, 0.2SeNPs/0.75R ; 0.2SeNPs/ 1.0R mg/ml (Shakibaie et al. 2015, Menon et al. 2020, Abozahra et al. 2020). All the test tubes were incubated for 48 hrs – 5 days at 28-30°C (for fungi) and 24-48 hrs at 37°C (for bacteria). The experiment was repeated twice and the MIC for fungi and bacteria was defined as the lowest Se-NPs concentration that showing no visible fungal or bacterial growth after incubation time. Also, 5 µL of tested broth were inoculated on the sterile nutrient agar plates for bacteria and SDA plate for fungi and incubated at 37°C for 24 hrs - 2 weeks. The lowest levels of Se-NPs and rosemary oil that inhibiting the visual growth of the test cultures on the agar plate were reported as MIC. The turbidity of the growth in tubes was observed every 24 hrs. The growth was assayed by measurement of optical density and transmittance % of each tube’s content at 405 nm using a spectrophotometer (NCCL - M27-A2, 2002).

Application of SeNPs singly and in combination with Rosemary for control of A. fumigatus and Kl. pneumoniae growth on sterilized yellow corn (Gupta and Kohli 2003)

The same procedures were repeated using sterilized commercial yellow corn contaminated with a spore suspension of A. fumigatus or Kl. pneumoniae instead of synthetic media. The total colony count of A. fumigatus or Kl. pneumoniae was evaluated before and after treatment.

Statistical analysis

The statistical evaluation was done by SPSS version 21 software package (SPSS, Inc, USA) through one-way ANOVA followed by Dunnett tests for control negative group (G1) comparison and p value ≤ 0.05 was considered statistically significant. All data were tabulated as Means±SD. according to SPSS 14 (2006).

RESULTS AND DISCUSSION

In the present study, a total of 120 samples were collected from private cattle farms with respiratory manifestation (70 nasal swabs, 25 drinking water, and 25 animal rations). The presented samples examined for isolation and identification of bacterial and fungal pathogens causing respiratory manifestations in dairy cattle with special reference to A. fumigatus and Kl. pneumoniae. The obtained tabulated results in Table 1 showed that the prevalence rates of A. fumigatus were...
14.28%, 12%, and 32% in the nasal swab, drinking water, and animal ration, respectively. Other species were identified as A. flavus, penicillium, fusarium, and Mucor sp. in different comparatively low frequencies. Moreover, yeast species were recovered from the nasal swabs as, Candida albicans 7.1%, Geotrichum sp. 2.8%, and Trichosporum sp. 1.4%. Similar results have already been reported by Al-Khalidi et al. (2012). On the other hand, Kl. pneumoniae is a facultatively anaerobic, Gram-negative bacterium of the Enterobacteriaceae family, and a reported opportunistic pathogen. Several studies recorded it as the main cause of pneumonia in mammals (Newire et al. 2013). The invasion of Kl. pneumoniae in the domestic animal has a potential threat to public health since these animals can act as a reservoir of multidrug-resistant Kl. pneumoniae strains (Cheng et al. 2018). Regarding results reported in Table 1, it is evident that the prevalence of Kl. pneumoniae isolated from examined nasal swab, water and rations were 17.14%, 0%, 8%, respectively. While, Kl. oxytocha recorded in 7.14%, 0%, 4% of examined nasal swab, water and rations samples, respectively. On the other hand, Pseudomonas aeroginosa, Staph. aureus and Strept. pyogenes were isolated from the examined nasal swabs in a percentage of 4.28%, 2.85%, and 2.85% respectively. It is common to detect pulmonary mixed infection as in the bovine respiratory tract which acts as reservoirs for pathogenic microorganisms that cause pneumonia (Moustafa 2004). Approx. 2.8% of examined nasal swab samples showed mixed infection with A. fumigatus and Kl. pneumoniae, while, there is no mixed infection recorded in ration and water samples. These results may be attributed to the antagonistic interactions between Kl. pneumoniae and several Aspergillus species including A. fumigatus, where, Kl. pneumoniae can prevent Aspergillus sp. spores germination and hyphae development (Nogueira et al. 2019).

In the present study, A. fumigatus was resistant to Fluconazole and Amphotericin B. However, it was sensitive to Voriconazole and Itraconazole at the rate of 70% and 80% respectively. Moreover, Klebsiella spp. were 100% resistant for each of E.Mox Clav (AMC30), Rifampicin (RD5) and Erythromycin (10µg). On the other hand, the isolates were sensitive to Ampicillin Sulbactom (SAM20), Nitrofurantion (F300), Amikacin (30µg), Oxytetracyclin (Ot30), and Oxacillin (OX1) in a percentage of 41.6%, 66.6%, 75%, 83.3%, 83, and 3% respectively. Today, the frequent use of traditional antibiotics that are resisted by some pathogens resulted in drug resistance and failure of disease treatments and this becomes a major world health concern (Hassan et al. 2020).

Herein, the used SeNPs were synthesized by green method to form glucose stabilized SeNPs from an aqueous sodium selenosulphate precursor under ambient conditions and the characterized NPs have amorphous powder form and the particles size was (60 nm) detected using TEM (Transmission electron microscopy). The formation of selenium nanoparticles in presence of glucose is primarily authenticated from UV-Vis spectrophotometry (Fig.1). They are safe methods and environmentally friendly and available for large-scale production. The organisms may cause changes in the toxic metals by decreasing the toxic effects (Inregole et al. 2010).

In the present study, the Se-NPs were evaluated for inhibition of the growth of A. fumigatus and Kl. pneumoniae that isolated from nasal swabs, drinking water, and ration. The recorded results were shown in (Table 2) illustrated that the MIC of Se-NPs against A. fumigatus was (0.4 mg/ml) and it was (0.5 mg/ml) for Kl. pneumoniae. The optical density of treated spore suspension was decreased till reach zero and transmittance 100%.
These results were confirmed by re-cultivation of inoculums from treated tubes onto the specific medium SDA for fungi and nutrient agar for bacteria. Shahverdi et al. (2010) investigated that the complete inhibition of *A. fumigatus* was seen in the presence of 80 µg/ml of biogenic selenium nanoparticles. Eswarapriya and Jegatheesan (2015) detected the antifungal potential of biogenic selenium nanoparticles. Eswarapriya and A. fumigatus et al. SDA for fungi and nutrient agar for bacteria. Shahverdi inoculums from treated tubes onto the specific medium Selenium Nanoparticles (Se NPs) against *Hariharan gram-negative bacteria was detected by many authors (Hariharan et al. 2012). Menon et al. (2020) found that the inhibition zone of Se-NPs against *Kl. pneumoniae* measured 10.5 ± 0.2 mm at a concentration of 100 µg/ml.

On the other hand, the antimicrobial potential of Rosemary oil against *A. fumigatus* and *Kl. pneumoniae* (Table 2) indicated that the Optical density and transmittance were concentration-dependent. When the concentrations of Rosemary increased up to 0.75 mg/ml, the optical density of treated *A. fumigatus* was decreased till reach 100% transmittance and clear medium. On the other hand, the inhibitory concentration of Rosemary oil that inhibited the growth of *Kl. pneumoniae* was 1.0 mg/ml. Herein, the antifungal potential of Rosemary oil against *Aspergillus* sp. was confirmed by Mihai and Popa (2015). Abozahra et al. (2020) determined the antimicrobial effect of rosemary against *Kl. pneumoniae*. The mechanism antimicrobial mechanisms of action of plant essential oils are suggested to be due to their contents of hydrophobic bioactive compounds which destruction of microbial cell walls and cell functions (Souza et al. 2013). They added that the contents of the oil affect ATP production, prevent cell protein synthesis, induce cytoplasmic changes and interfere with quorum sensing.

In the present study, results in (Table 3) showed the combined antimicrobial potentials of SeNPs with Rosemary against bacteria and fungi. It is obvious that the MIC of SeNPs against *A. fumigatus* and *Kl. pneumoniae* was decreased to 0.1 mg/ml when combined with Rosemary 0.75 mg/ml. The synergistic and combination therapy of SeNPs with the essential oil additives decreases the used concentration of nanoparticles. There have been numerous studies that have reported the potential of both essential oils and metal/metal oxide nanocomposites with broad spectra of bioactivities including antioxidant, anticancer, and antimicrobial activities (Hassan et al. 2020). Combination therapy represents an important field that needs greater attention and future investigations (Basavegowda et al. 2020).

Currently, obtained findings in (Table 4) showed that the inhibitory effect of SeNPs against *A. fumigatus* and *Kl. pneumoniae* in the ration which revealed that the MIC was 0.3 mg/ml and 0.4 mg/ml, respectively. Whereas, the combination of polluted rations with SeNPs and Rosemary oil caused a reduction in MIC of SeNPs to 0.1mg/ml for each.

Similarly, Hassan et al. (2017), detected the significantly stronger antimicrobial potentials of ZnNPs in conjugation with cinnamon oil or ozone than their single activities against bacteria and fungi. Also, the essential oil additives loaded into mesoporous silica nanoparticles can suppress the growth of fungi (Bernardos et al. 2015). The combination of nanoemulsions and matrix of certain nanostructures such as lipids and polysaccharides were more effective in the inactivation of bacteria than the traditional and classical emulsions and used lower doses (Salvia-Trujillo et al. 2017). On the other hand, there are several mechanisms of antimicrobial activity of NPs included contact of NPs and penetration of the cell walls, destroying a microbial cell generating ROS release of metals ions and caused oxidative stress (Rudramurthy et al. 2016). The release of metallic ions resulted in depolarization of cell membranes, lipid peroxidation, protein oxidation, and DNA damage (Huang et al. 2020). Based on oxidative stress, Chang et al. (2012) found that NPs may enter the

| Tested isolates | Mean log CFU/ml at gradual concentrations of SeNPs | 0.1 SeNPs/0.75 R | 0.2 SeNPs/0.75 R | 0.1 SeNPs/0.1 R |
|-----------------|--------------------------------------------------|------------------|------------------|------------------|
| *A. fumigatus*  | Non treated (N.T.) 3.3±0.18 | 1.9±0.04 | 0.7±0.054 | 00 | 00 | 0.1 SeNPs/0.75 R | 00 | 00 | 00 |
| *Kl. pneumonia* | 3.1±0.11 | 2.17±0.22 | 1 ±0.036 | 0.6±0.73 | 00 | 00 | 0.1 SeNPs/0.1 R | 0.3±0.085 | 00 | 00 |
microbial cells via the endocytosis process this related to induction ROS and the ions released by the nanostructures. While, Jay and Shafkat (2018) reported that Se-NPs destroyed the cell wall, leakage of cytoplasm contents, and loss of treated fungal and bacterial cell functions as detected when they subjected to SEM. While, Zhao et al. (2018), found that high stress due to the accumulation of SeNPs on the surface of cells stimulated the production of ROS which help in the inhibition of bacterial cells. Also, Se-NPs destructed the cell wall, leakage of cytoplasm contents and loss of treated fungal and bacterial cell functions as detected when they subjected to SEM (Jay and Shafkat 2018). The synergistic and combination therapy of SeNPs with oils is of significant importance to reduce the used levels of metals NPs, avoid the microbial resistance to traditional antibiotics, and resulted in more efficient antimicrobial activity in the therapy of human and animal diseases. Moreover, there will be several benefits of metallic nanomaterials to be used in improving biomedical applications. Although, data related to their harmful not sufficient and special attention is required for known their toxicity risk before to biomedical applications. Hence, future several toxico logical studies are needed before nanotechnology applications in biomedicine and animal health.

**CONCLUSION**

Our forgoing results concluded that respiratory diseases are responsible for huge economic losses in livestock especially in large ruminants due to important burdens to the country’s economy regarding meat, milk, wool, and leather industries. Hence, the frequent testing program of the animal feeds and other environmental factors for fungal and bacterial contamination is a critical demand. The metals nanomaterials are used as antimicrobial agents besides other benefits strategies as disease detection, diagnosis and therapy, additives to food, feeds and their products, and finally food safety. Our results detected that Se-NPs and rosemary oil administration have significant antimicrobial potential against fungal and bacterial causes of respiratory infection and their combination showed the requirement of lower concentrations from both (0.1 mg/ml Se-NPs in combination with Rosemary 0.75mg/ml) to obtain significantly higher antimicrobial effects than their single form. This combination resulted in decreasing the concentrations from both to obtain the antimicrobial effects. Therefore, synergistic therapy is needed to reduce the used levels of metal nanoparticles and hence overcome their toxicity and more efficient antimicrobial activities occurred.

**REFERENCES**

Abozahra R, Abdelhamid SM, Wen MM, Abdelwahab I, Baraka K (2020) A nanoparticles based microbiological study on the effect of rosemary and ginger essential oils against Klebsiella pneumoniae. The Open Microbiol J 14: 205-212.

Al-Khalidi AA, Alwan MJ, Faraj MK (2012) Isolation and identification of fungi associated with chronic respiratory infections in human and bovine. Al-Anbar J Vet Sci 5: 85-93.

Balachandran RS, Heighington CS, Starostina NG, Anderson J W, Owen DL et al. (2016) The ubiquitin ligase CRL2ZYG11 targets cyclin B1 for degradation in a conserved pathway that facilitates mitotic slippage. J Cell Biol 215: 151-166.

Barkema HW, Von Keyserlingk MAG, Kastelic JP, Lam TJGM, Luby C et al. (2015) Invited review: Changes in the dairy industry affecting dairy cattle health and welfare. J Dairy Sci 98: 7426-7445.

Barreto HM, Filho ECS, Lima EO, Coutinho HDM, Morais-Braga MFB et al. (2014) Chemical composition and possible use as adjuvant of the antibiotic therapy of the essential oil of Rosmarinus officinalis L. Industrial Crops Products 59: 290-294.

Basavegowda N, Patra JK, Baek K (2020) Essential oils and mono/bi/tri-metallic nanocomposites as alternative sources of antimicrobial agents to combat multidrug-resistant pathogenic microorganisms: an overview. Molecules 25: 1058.

Bernardos A, Marina T, Zacek P, Pérez-Esteve É, Martinez-Mañez R et al. (2015) Antifungal effect of essential oil components against Aspergillus niger when loaded into silica mesoporous supports. J Sci Food Agricult 95: 2824-2831.

Chang YN, Zhang M, Xia L, Zhang J, Xing G (2012) The toxic effects and mechanisms of CuO and ZnO nanoparticles. Materials 5: 2850-2871.

Cheng F, Li Z, Lan S, Liu W, Li X et al. (2018) Characterization of of Klebsiella pneumoniae associated with cattle infections in southwest China using multi-locus sequence typing (MLST), antibiotic resistance and virulence-associated gene profile analysis. Brazilian J Microbiol 49: 93-100.

CLSI (2008) Reference method for broth dilution antifungal susceptibility testing of filamentous fungi, 2 nd edn. CLSI standard M38. Wayne, Pennsylvania, 19087-1898 USA.

Cruickshank R, Duguid JP, Marmion BP, Swain RH (1975) Medical Microbiology (12th edn) Longman group Ltd. Edinburgh, London, 180-188.
Eswarapriyaa B, Jegatheesan KS (2015) Antifungal activity of biogenic selenium nanoparticles synthesized from electronic waste. Intern J Pharmaceut Technol Res 8: 383-386.

Fouda A, Hassan SE, Abdo AM, El-Gamal MS (2020) Antimicrobial, antioxidant and larvicidal activities of spherical silver nanoparticles synthesized by endophytic Streptomyces spp. Biological Trace Element 195: 707-724.

Geoffrion LD, Hesabizadeh T, Medina-Cruz D, Kusper M, Taylor P et al. (2020) Naked selenium nanoparticles for antibacterial and anticancer treatments. American Chemic Soc Omega 5: 2660-2669.

Gupta AK, Kohli Y (2003) In vitro susceptibility testing of ciclopirox, terbinafine, ketoconazole and itraconazole against dermatophytes and non dermatophytes, and in vitro evaluation of combination antifungal activity. British J Dermatology 149: 296-305.

Hariharan H, Al-Harbi N, Karuppiah P, Rajaram S (2012) Microbial synthesis of selenium nanocomposite using Saccharomyces cerevisiae and its antimicrobial activity against pathogens causing nosocomial infection. Chalcogenide Letters 9: 509-515.

Hassan AA, El-Shafei HM, Sayed EARMH, El-Hamaky AM (2017) Molecular detection the influence of aflatoxin biosynthetic genes by Aspergillus flavus before and after Bacillus subtilis and Candida albicans biocontrol. 9th Scient Congr Egypt J Anim Manag, 1-19.

Hassan AA, Mansour MK, El Hamaky AM, Syed EARH, Oraby NH (2020) Ch 24: Nanomaterials and nanocomposite applications in veterinary medicine. In: Multifunctional hybrid nanomaterials for sustainable agri-food and ecosystems. Elsevier 583-638.

Huang W, Yan M, Duan H, Bi Y , Cheng X et al. (2020) Synergistic antifungal activity of green synthesized silver nanoparticles and epoxiconazole against Setosphaeria turcica. J Nanomaterials 7(9535432): 1-7.

Husen A, Siddiqi KS (2014) Plants and microbes assisted selenium nanoparticles: characterization and application. J Nanobiotechnology 12(28): 122-125.

Inregole AR, Thakare SR, Khati NT, Wankhade AV, Burghate DK (2010) Green synthesis of selenium nanoparticles under ambient condition. Chalcogenide Letters 7: 485-489.

Jay V, Shafkat R (2018) Synthesis of selenium nanoparticles using Allium sativum extract and analysis of their antimicrobial property against gram positive bacteria. The Pharma Innovat J 7: 262-265.

Koneman EW, Allen, SD, Janda WM, Scheckenberger PC, Winn WC (1992) Color atlas and textbook of Diagnostic Microbiology. 4th edn. J.B. Lippincott Co. Philadelphia, 253-320.

Meena NS, Sahni YP, Thakur D, Singh RP (2018) Applications of nanotechnology in veterinary therapeutics. J Entomol Zool Stud 6: 167-175.

Menon S, Shanmugam V (2019) Cytotoxicity analysis of biosynthesized selenium nanoparticles towards A549 lung cancer cell line. J Inorganic Organometallic Polymers Materials 30: n1852-1864.

Menon S, Agarwal H, Rajeshkumar S, JacqulineRosy P, Shanmugam VK (2020) Investigating the antimicrobial activities of the biosynthesized selenium nanoparticles and its statistical analysis BioNanoScience 10: 122-135.

Mihai AL, Popa ME (2015) In vitro activity of natural antimicrobial activity compound against Aspergillus strains. Agricult Agricultural Scie Procedia 6: 585-592.

Moustafa AH (2004) Study of some aerobic bacterial causes of respiratory affection in slaughtered camels in Dakahlia Governorate. Assuit Veterinary Medical J 50: 95-105.

NCCLS (2004) Performance standards for antimicrobial disc susceptibility testing: fourteenth informational supplement M 100-514, NCCLS, Wayne, PA, USA.

NCCLS M27-A2 (2002) Reference method for broth dilution antifungal susceptibility testing of yeasts: Approved standard M27-A2, 2nd edn. National Committee for Clinical Laboratory Standards, Villanova, Pa.

Newire EA, Ahmed SF, House B, Valiente E, Pimentel G (2013) Detection of new SHV-12 S, HV-5 and SHV-2a variants of extended spectumbeta-lactamase in Klebsiella pneumoniae in Egypt. Annal Clinic Microbiol Antimicrobials 1: 12-16.

Nogueira MF, Pereira L, Jenull S, Kuchler K, Lion T (2019) Klebsiella pneumoniae prevents spore germination and hyphal development of Aspergillus species. Scientific reports 9: 218-222.

Oblinger JL, Koburger JA (1975) Understanding and teaching the most probable number technique. J Milk Food Technol 38: 540-545.

Pitt JI, Hocking AD (2009) Fungi and food spoilage: methods for isolation, enumeration and identification, 3rd edn. Springer Science International Publishing, New York. 21-57.
Quinn PJ, Carter ME, Markey BK, Leonard FC, Hartiau P et al. (2011) Veterinary Microbiology and Microbial diseases 2nd edn. Wiley-Blackwell publisher, USA.

Rai M, Parlikar P, Jogee P, Agarkar G, Ingle AP et al. (2017) Synergistic antimicrobial potential of essential oils in combination with nanoparticles: Emerging trends and future perspectives. Intern J Pharmaceutics 519: 67-78.

Refai MK, Abo El Yazied H, El Hariri M (2012) Monograph of yeast (Updated). http://www cairo.academic.edu/Mohamed Refai.

Rudramurthy G, Swamy M, Sinniah U, Ghasemzadeh A (2016) Nanoparticles: alternatives against drug-resistant pathogenic microbes. Molecules 21: 836-842.

Salvia-Trujillo L, Soliva-Fortuny R, Rojas-Graü MA, McClements DJ, Martin-Belloso O (2017) Edible nanoemulsions as carriers of active ingredients: a review. Annual Rev Food Sci Technol 8: 439-466.

Seyedmousavi S, Brüggemann RJ, Meis JF, Melchers WJ, Verweij PE et al. (2015) Pharmacodynamics of isavuconazole in an Aspergillus fumigatus mouse infection model. Antimicrobial Agents Chemotherapy 59: 2855-2862.

Shahverdi AR, Fakhimi A, Mosavat G, Jafari-Fesharaki P, Rezaie S et al. (2010) Antifungal activity of biogenic selenium nanoparticles. World Applied Sciences J 10: 918-922.

Shakibaie M, Mohazab NS, Mousavi SAA (2015) Antifungal activity of selenium nanoparticles synthesized by Bacillus species MSH-1 against Aspergillus fumigatus and Candida albicans. Jundishapur J Microbiol 8: e26381.

Singh A, Chhabra R, Sikrodia S, Shukla S, Sharda R et al. (2018) Isolation of E. coli from bovine mastitis and their antibiotic sensitivity pattern. Int J Current Microbiol Applied Sci 7: 11-18.

Souza EL, Oliveira CE, Stamford TLM, Conceição ML, Gomes Neto NJ (2013) Influence of carvacrol and thymol on the physiological attributes, enterotoxin production and surface characteristics of Staphylococcus aureus strain isolated from foods. Brazilian J Microbiol 44: 29-35.

SPSS 14 (2006) Statistical Package for Social Science (2006) Standard Version. © SPSS Inc. USA.

Zhang J, Shi W, Ma Q, Cui H, Zhang L (2021) Application of nanotechnology in immunity against infection. Coatings 11: 430-433.

Zhao G, Wu X, Chen P, Zhang L, Yang CS et al. (2018) Selenium nanoparticles are more efficient than sodium selenite in producing reactive oxygen species and hyper-accumulation of selenium nanoparticles in cancer cells generates potent therapeutic effects. Free Radical Biolo Medic 126: 55-66.

Zheng Y, Chen T (2012) Targeting nanomaterials: future drugs for cancer chemotherapy. Intern J Nanomedicine 7: 3939-3949.

*Cite this article as: Hassan AA, Iskander D, Oraby NH (2022) Evaluation of the synergistic antimicrobial activities of selenium nanoparticles and rosemary oil against Aspergillus fumigatus and Klebsiella pneumoniae recovered from respiratory infection in cattle in Giza Governorate, Egypt. Explor Anim Med Res 12(1): 24-32. DOI: 10.52635/eamr/12.1.24-32.