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Production of clothes for beach volleyball players: Safe against ultraviolet radiation damage

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Abstract. Volleyball is an international sport with many fans. This sport has made significant progress in schools and clubs. Volleyball is suitable for all age groups and can be used in different environments. It has many social and physical benefits. During the game provides special physical training for the players and is considered one of the most exciting games. Another type of volleyball is beach volleyball, a beach sport and one of the Olympic sports held on the sand with the same rules as volleyball. This sport is usually played in coastal areas, especially with wide sandy beaches. Because this sport is played in open spaces, the players stay in this space for a long time and are exposed to dangerous ultraviolet radiation. It is a wavelength of light in the range of electromagnetic waves with a wavelength between 10 and 400 nm. This wavelength is shorter than visible light and more protracted than X-ray. Ultraviolet (UV) rays are naturally present in sunlight and include about 10% of all waves emitted from the sun's surface. Prolonged exposure to ultraviolet light causes acute and chronic damage to the skin and vision and even destroys the entire immune system. Different covers of the earth's surface reflect different amounts of UV rays. For example, snow cover, sand, and seawater surface reflect this radiation. Therefore, the health of volleyball players is in danger due to this harmful radiation. This work aims to introduce a type of clothing made of nanoparticles that can repel ultraviolet rays and protect beach volleyball players whose health is at risk from this radiation.

Keywords: clothes; radiation damage; safe; ultraviolet radiation; volleyball beach

1. Introduction

Volleyball is a simple game and can be played by all age groups indoors or outdoors (Hou *et al.* 2021, Huang *et al.* 2021, Xu *et al.* 2021, Wang *et al.* 2022). In many regions of the world, it is known as one of the most basic recreational sports and in other regions as one of the competitive sports (UNICEF 2004). Volleyball is not only a good game but also an exciting training sport for athletes, swimmers, and players of other sports (Steinfeldt *et al.* 2012). It requires jumping, agility, speed, reaction, and adjusting movements in the designated time (Ho *et al.* 2015). Volleyball was born in America in 1895, and its world fame spread after the 1964 Tokyo Olympics, which was included in the Olympics program for the first time (Kluka and Hendricks 2020). Although volleyball was an indoor sport at the beginning, it was played in indoor places and was reserved for the fun activities of professionals and business people (Ghadiri and Shafiei 2016c, Ghadiri *et al.* 2016c, Ghadiri *et al.* 2017c, Shafiei *et al.* 2017a, Shafiei *et al.* 2020). However, it was gradually extended to open fields, became one of the exciting summer activities, and was followed strongly (Rasmussen and Dalsgaard 2023). Beach volleyball is an Olympic sport held on the sand with the same rules as volleyball. The history of beach volleyball is more than half a century (Madaminov 2021). A sport whose starting philosophy was more about entertainment than winning medals and competing with today's prominent sports in the world (Pérez-Turpin *et al.* 2019). The history and audience's acceptance of this sport caused volleyball to surpass other beach sports, such as football and handball (Wergin *et al.* 2020). It is expressed that the first origin of beach volleyball was on the coast of South America, which gradually became popular with the joining of Europe and Oceania (Fasold *et al.* 2022). This game has many similarities with indoor volleyball, including the similarities between the two in the presence of referees. Each game has a head referee, two line referees, and an assistant referee (Nakamura 2019).

Nevertheless, there are also differences with an indoor volleyball (Mesquita *et al.* 2013). In this game, there are only two players in each team who are allowed to stand anywhere on the court, and only the captain can request a rest (Bahr and Reeser 2003). In this game, there are no reserve players, and in case of any problem or injury for any of the players, according to the existing law, this game will end 2-0 in favor of the opposing team (Gomez *et al.* 2014). Another difference between it and the volleyball that is held in the hall is its ball, the ball of this game is remarkable for the open space (Adamian *et al.* 2020, Al-Furjan *et al.* 2020a, Al-Furjan *et al.* 2020b, Li *et al.* 2020b, Zare *et al.* 2020, Dai *et al.* 2021). The game consists of three games with a 30-second break between each game, and the team that wins two games wins; clearly, any team that is 2-3 is declared the winner of the game (Shafiei *et al.* 2016g,

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Ghadiri *et al.* 2017d, Shafiei *et al.* 2017d, Azimi *et al.* 2018). There is a possibility of rain and storm in this game, but if it is mild, the game will not be interrupted, and the game will continue (Bahr and Reeser 2003, Cao *et al.* 2021a).

Nevertheless, most of the time, this game is played under the sun. Sunlight consists of different rays (Al-Furjan *et al.* 2020c, Al-Furjan *et al.* 2020d, Al-Furjan *et al.* 2020f, Bai *et al.* 2020, Li *et al.* 2020a, Zhang *et al.* 2020, Guo *et al.* 2021, Liu *et al.* 2021). These rays emitted from the sun are divided into three categories: ultraviolet A (UVA), ultraviolet B (UVB), and ultraviolet C (UVC) (Cao *et al.* 2021b). The radiation of these rays varies throughout the day, and its intensity is between 10 am and 3 pm (Azimi *et al.* 2016, Ghadiri and Shafiei 2016b, Ghadiri *et al.* 2017b, Shafiei *et al.* 2017b). During these hours, if a person goes under the sun without protection, his skin will suffer greatly (Ghadiri *et al.* 2016a, Ebrahimi *et al.* 2017, Mirjavadi *et al.* 2017a, Mirjavadi *et al.* 2017b). Their radiation is felt more on sunny days, while on cloudy days, they can easily pass through the clouds and reach the earth's surface (Hashemi *et al.* 2019, Al-Furjan *et al.* 2020e, Cheshmeh *et al.* 2020, Lori *et al.* 2020, Najaafi *et al.* 2020, Shariati *et al.* 2020b). The amount of UV radiation has nothing to do with temperature, so their strength may be greater on the coldest days of the year than on hot summer days (Misovic *et al.* 2013). People may be unaware of the harmful effects of sunlight on the skin and think sunlight is only beneficial for them (Shafiei *et al.* 2016d, Shafiei *et al.* 2016f, Ghadiri *et al.* 2017a, Shafiei and She 2018). The sun's ultraviolet rays damage the skin's DNA (Hashemi *et al.* 2019, Moayedi *et al.* 2019, Moayedi *et al.* 2020a, Moayedi *et al.* 2020b, Oyarhossein *et al.* 2020, Shariati *et al.* 2020a). In order to protect these cells, the skin produces melanin, a type of pigment that prevents further damage to the skin (Shafiei *et al.* 2016c, Shafiei *et al.* 2016e, Mirjavadi *et al.* 2017d, Mousavi *et al.* 2017). Finally, these pigments cause brown skin. The longer the wavelength of a ray, the more penetration it has, but its energy is lower, and conversely, the shorter the wavelength of the ray, the more energy it has and less penetration (Arthey and Clarke 1995). UVB rays have more energy and burn the skin's surface with their energy, but due to their low penetration, they cannot reach the lower surface of the skin (Ghadiri and Shafiei 2016a, Shafiei *et al.* 2016b, Shafiei and Kazemi 2017b, Shafiei *et al.* 2017c). Therefore, the leading cause of sunburn is ultraviolet rays with UVB wavelength (Habibi *et al.* 2019, Safarpour *et al.* 2019, Alipour *et al.* 2020, Ebrahimi *et al.* 2020, Chen *et al.* 2022). Since UVA rays have a shorter wavelength, they do not cause skin burns, but because they penetrate the deeper layers of the skin, they are known to be the leading cause of skin aging (Egambaram *et al.* 2020). It damages the collagen fibers in the skin's dermis and causes abnormal elastin production (Ghadiri *et al.* 2016b, Ghadiri *et al.* 2016d, Ghadiri *et al.* 2017e, Shivanian *et al.* 2017). This abnormal elastin produces the metalloprotease enzyme that can repair damaged collagen (Yi *et al.* 2019).

Nevertheless, it usually destroys collagen tissue (Omidi *et al.* 2013, Ebrahimi and Shafiei 2017, Ehyaei *et al.* 2017, Shafiei *et al.* 2019). Incomplete and incorrect skin regeneration causes skin wrinkles. Sun damage on the skin is different for each person (Li *et al.* 2021, Si *et al.* 2021, Zhang *et al.* 2021, Cheng *et al.* 2022, Li *et al.* 2022, Cao *et al.* 2023). Therefore, the harmful effects of sunlight on the skin and aging caused by this factor differ for each person. Skin spots are one of the most common injuries that cause brown spots on the skin (Mohiuddin 2019). The spots may have a gray or dark brown color, and the places where this spot is created are mostly protruding nose, forehead, chin, and lips (Ebrahimi and Shafiei 2016, Shafiei *et al.* 2016a, Mirjavadi *et al.* 2017c, Shafiei and Kazemi 2017a). Actinic keratosis or solar keratosis can be mentioned as other damages caused by sunlight (Bruyn *et al.* 1989). It is caused by direct sunlight and increases the risk of cancer. Changes in the skin's texture cause deep lines as well as firmness and leatheriness, which destroy the smoothness and softness of the skin (English *et al.* 1997). Other harmful effects of sunlight on the skin include blood vessels that have turned into red spots or spots on the nose due to sunlight. These radiations are so powerful that sometimes clothing or even glass does not prevent their penetration and can cause severe damage to the skin. When the amount of radiation of these rays is long and high, the skin will be in danger (Pathak *et al.* 1982). UVC rays are the strongest and deadliest rays emitted by the sun, but fortunately, the ozone layer prevents them from reaching the earth's surface. In addition to wearing the right clothes at work, it is also necessary to wear the right sports clothes in sports places (Dallavecchia *et al.* 2019). This is important since the correct type of clothing can help the athlete achieve the benefits of the workout they are involved in. The right type of sportswear protects the athlete from the possibility of injury. Proper clothing can help protect muscles from possible inflammation and injury. Before starting any sport, appropriate clothing should be worn to minimize possible injuries during the sport (Lincoln 1992). Achieving sports products with improved performance and efficiency is one of the manufacturers' goals. In the meantime, nanotechnology has created new ways to produce functional sportswear (Gong 2013). The use of nanotechnology in textile materials, including nanofibers and nanocomposite fibers, as well as finishing textiles with nanomaterials, creates multiple properties in textiles, which makes their use attractive in the sportswear market (Joshi and Bhattacharyya 2011). The use of nanoparticles with protective properties of ultraviolet rays in sportswear Due to the risk of skin damage related to this radiation, it has received particular attention, especially in outdoor sports (Silveira and Pedroso 2014).

Among the organic and inorganic UV protective materials, semiconductors such as titanium dioxide (TiO_2), zinc oxide (ZnO), silicon dioxide (SiO_2), and aluminum oxide (Al_2O_3) are preferred due to their chemical stability, low cost, are more valuable (Anu Mary Ealia and Saravanakumar 2017). The availability and non-toxicity of the performance of UV blocking agents can be increased by uniformly distributing the nanoparticles on the fabric (Abou Elmaaty *et al.* 2022). The particles contain a lot of surface area in a small volume, which means that they interact more with fungi and bacteria. Furthermore, they prevent their

Table 1 List of materials and equipment

Materials	*Equipment*
Allium ampeloprasum	Magnetic stirrer
Distilled water	Oven
Methanol	pH meter
Selenous acid	Centrifuge
Clostridium perfringens type D	Scanning electron microscope (SEM)
	Incubator
	Fourier-transform infrared spectroscopy (FT-IR)

growth and reproduction (Khezerlou *et al.* 2018). Sports is a physical activity that is done to create health and also increases physical fitness. If it is followed professionally, this physical activity is done. It becomes a professional sport, generating income for the athlete as a career (Campos-Izquierdo *et al.* 2016). Safety is vital in sports because if an athlete has an accident, he may not be able to live a daily life for the rest of his life (Fares *et al.* 2022). Selenium is an essential element in the body. The lack of which in the body can cause serious problems for a person and, in severe cases, can even be fatal (Minich 2022). This element exists in two organic and inorganic forms: Selenium participates in the structure of selenocysteine amino acid compounds in synthesizing several selenoenzymes such as glutathione peroxidase, iodothyronine deiodinase (regulating thyroid hormone activity) and thioredoxin reductases (repairing antioxidant systems). Nanoselenium is more effective and efficient than organic and inorganic sources of selenium, such as selenite, selenomethionine, and methyl cysteine, and it is also less toxic (Banerjee *et al.* 2022). Selenium nanoparticles are the subject of much research due to their essential commercial and therapeutic applications. Selenium nanoparticles act as potent antioxidants and are much less toxic than selenium. Due to their antioxidant properties, they have high power in eliminating free radicals, are used in treating skin infections, are immune system modulators, and have antibacterial properties (Sentkowska and Pyrzyńska 2022).

Allium ampeloprasum is an herbaceous plant with a spicy taste similar to onion syrup, and its appearance is similar to greens. It can be consumed raw, like a vegetable with food. This plant is diuretic and thus removes excess moisture from the body, reduces stomach moisture, and improves digestion, suitable for treating shortness of breath (Polito *et al.* 2022). It reduces blood pressure by dilating blood vessels, increases appetite, reduces inflammation caused by insect bite venom, and acts as a pain reliever for sciatica, gout, and rheumatism. It has antiseptic properties and is beneficial for the intestines and digestive system. A substance called choline increases the learning power of children and adults (Lemma *et al.* 2022). It contains large amounts of vitamin A, which helps strengthen vision and prevent cataracts. It is an excellent protector of the heart, improves the immune system, and helps prevent various types of cancer. It helps the body to produce collagen (Mehrabani *et al.* 2022). In this work, for the first time, the green synthesis of selenium nanoparticles using plant source Allium ampeloprasum and the use of these plant nanoparticles as a blocker of harmful ultraviolet rays in the clothes of beach volleyball players and also the antimicrobial effect of this product in the shoes of these players will be investigated.

2. Materials

The list of materials and equipment used for the synthesis of nanoparticles to be used in the clothes of beach volleyball players and to protect them against ultraviolet rays is shown in Table 1.

3. Methods

3.1 Preparation of Allium ampeloprasum extract

Allium ampeloprasum was prepared fresh and placed in an oven at 30°C for 12 hours to dry. The dried part was extracted in a decanter ampoule using pure methanol solvent for 15 hours. Finally, the methanolic solvent was evaporated using a vacuum distillation apparatus, and the obtained methanolic extract was kept at 4°C.

3.2 Green synthesis of selenium nanoparticles

Selenous acid was the source of selenium salt for the green synthesis of selenium nanoparticles. Different concentrations of Allium ampeloprasum extract (0.2, 0.5, and 1% dissolved in distilled water) were placed on a magnetic stirrer at a speed of 300 rpm and a temperature of 25 degrees Celsius. Then, selenium was prepared with concentrations of 10, 15, and 20 mM and was added drop by drop to the extract under dark conditions. In the next part of the experiment, the effect of different pH of Allium ampeloprasum extract and the sampling duration on the green synthesis of nanoparticles were investigated. The natural pH of the extract was 2, other pH, including 4, 6, 8, and 9, were also evaluated.

Furthermore, 4, 24, 48, 72, and 120 hours durations were also investigated. The shape and size distribution of the prepared nanoparticles was done using a scanning electron microscope (SEM) image analysis. The Fourier-transform infrared spectroscopy was used to identify more characteristics of these nanoparticles. The ultraviolet-visible spectrum (UV-VIS) of selenium was also taken in the range of 300-500 nm.

3.3 Investigating the antibacterial activity of synthesized selenium nanoparticles

The antibacterial activity of selenium nanoparticles was tested on Clostridium perfringens type D by test tube method and Bactericidal Minimal Concentration (MBC). For this purpose, tubes containing 15 ml of tryptose soy broth (TSB) culture medium were prepared and sterilized. Then 2 µL of pre-prepared primary seed containing Clostridium perfringens type D bacteria were added to them. The specific amounts of

Fig. 1 Selenium nanoparticles

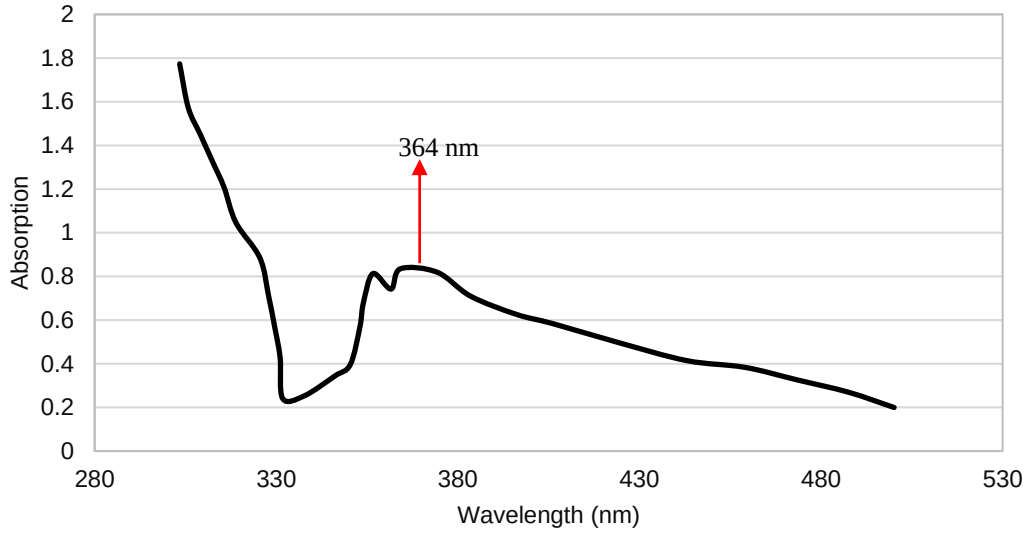

Fig. 2 Absorption spectrum of selenium nanoparticle

produced selenium nanoparticles (0 µg/ml-5000µg/ml) were added to each tube, and the results were obtained after three repetitions.

3.4 Preparation of clothes covered by nanoparticles

A fabric sample with dimensions of 10 × 15cm made of 100% cotton fabric with ring texture is subjected to the initial washing process. After the above step, the prepared fabric sample was subjected to heat treatment in the oven for 40 minutes at a temperature of 100ºC until it was scorched. Then the dried fabric sample was fully immersed in the prepared nanoparticle solution for 5 minutes. It was subjected to heat treatment in the oven for 10 minutes at a temperature of 80ºC, and after the drying stage, the cotton fabric was again heated at a temperature of 120ºC.

4. Results and discussion

4.1 UV spectroscopy

According to the obtained results, the color change of the solution from yellow to red was the first visible change indicating the production of selenium nanoparticles (Fig. 1). Then, to investigate the effect of factors such as the concentration of selenium extract and salt, pH, and sampling time on the absorbance, a visible spectrometer was used at a wavelength of 300 to 500 nm.

4.2 Effect of extracting Allium ampeloprasum concentration and selenium salt concentration

The visible spectrometer device showed that different concentrations of selenium extract and salt significantly affect the amount of nanoparticle absorption. The best effect in terms of absorbance was the concentration of 0.5% of the extract, along with the concentration of 20 mM selenium salt with an absorbance of 0.835 at a wavelength of 364 nm.

The subsequent effect was in the concentration of 1% of the extract and the concentration of 15 mM selenium salt, with an absorption rate of 0.813 at a wavelength of 356 nm (Fig. 2). By decreasing the concentration of salt and extract,

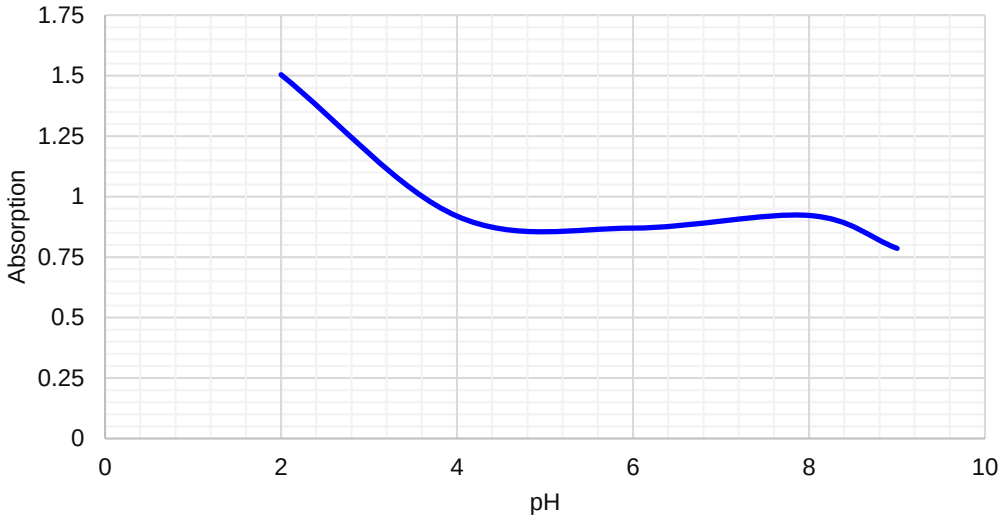

Fig. 3 The effect of pH on the optical absorption of nanoparticles

light absorption decreased. Increasing the concentration of the extract at fixed concentrations of salt and increasing the amount of salt at fixed concentrations of the extract caused an increase in absorption.

4.3 Effect of pH

In order to obtain suitable pH for the green synthesis of selenium nanoparticles, different pH of the extract was investigated. The results showed that the most suitable pH is 2 (Fig. 3). As the pH increases, the absorption of the solution containing nanoparticles decreases. Therefore, selenium is better regenerated in acidic pH and turns into nanoparticles. In this work, the sampling period was 24 hours.

4.4 SEM image of selenium nanoparticles

The obtained image of selenium nanoparticles synthesized by the plant source shows that the nanoparticles are widely distributed with a size close to about 60 nm, which indicates the stabilization of the nanoparticles by the limiting factors present in the Allium ampeloprasum extract (Fig. 4).

4.5 FTIR spectrum of selenium nanoparticles

As shown in Fig. 5, by comparing the results obtained from FTIR analysis, it can be said that the broad peak that appears in the wave number of 3200 cm^{-1} - 3500 cm^{-1} can be related to the NH group, OH group of water solvent or OH of phenolic or carboxylic acid. The peak in the 2900 cm^{-1} can be related to the stretching of the aliphatic C-H bond. The range of 1640-1690 cm^{-1} corresponds to the N=C group, and the range of 1474-1600 cm^{-1} is related to the benzene ring. Also, 2000-1500 cm^{-1} peak is related to the absorption of C=C, N=C, and O=C stretching double bonds. Also, the 1500 cm^{-1} peak is related to the absorption of C=C, N=C, and O=C stretching double bonds.

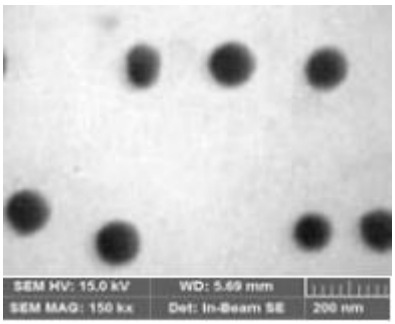

Fig. 4 SEM image of selenium nanoparticles

4.6 UV-resistant nanoparticle-coated sample

The reflectance spectrum obtained from the raw cotton fabric sample and the sample coated with nanoparticles in the wavelength range of 340 to 750 nm can be seen in Fig. 6. In the 340-450 nm limit, which corresponds to the ultraviolet region, the coated samples are more resistant to ultraviolet rays than the raw fabric.

4.7 Antibacterial activity

In the presence of Klebsiella pneumoniae, the selenium ions in the culture medium decreased. Selenium nanoparticles have shown excellent antibacterial properties, and in the MBCs test performed on them in the range of 0 µg/ml to 5000 µg/ml, it was found that these nanoparticles have bactericidal properties at 4012 µg/ml.

In recent decades, with the advent of nanotechnology, the use of nanoparticles has increased due to increased biological activity, improved targeted treatment, and reduced toxicity. Selenium is one of the essential elements in living organisms. This element is present in the structure of many enzymes that play different roles in the living organism. Several effects have been reported for selenium nanoparticles in different conditions. In this method, selenium nanoparticles have been used to block ultraviolet

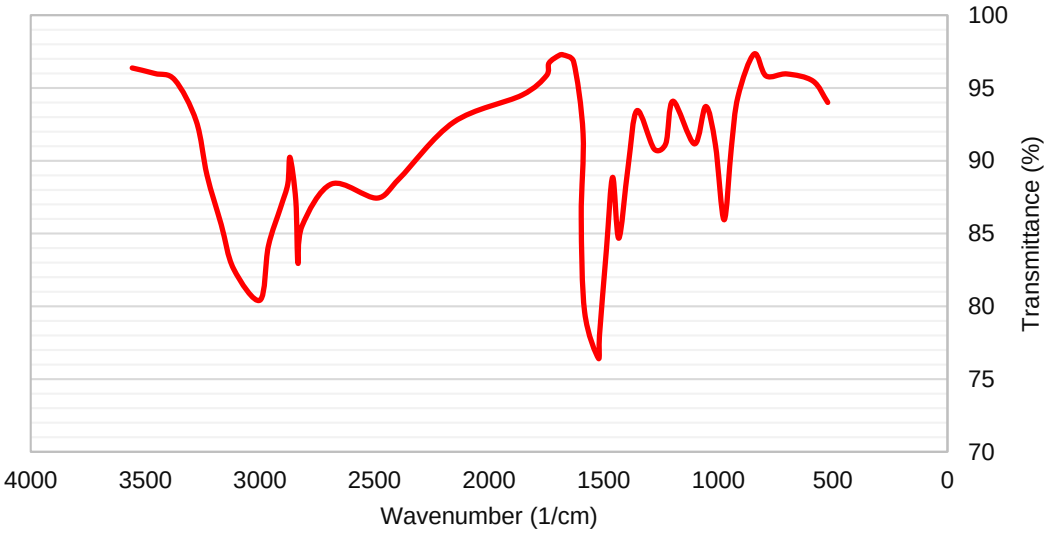

Fig. 5 FTIR spectrum of synthesized selenium nanoparticles

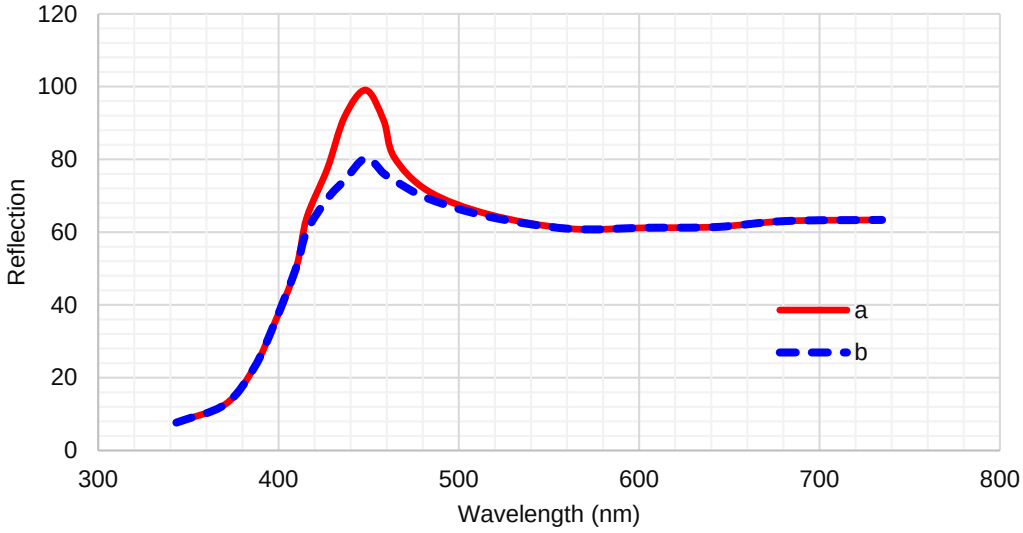

Fig. 6 Reflectance spectrum of raw cotton fabric (a), coated cotton fabric (b)

radiation through its coating on the clothes of beach volleyball players. The results of the green synthesis of this nanoparticle by the vegetable source of Allium ampeloprasum indicate a successful synthesis to repel ultraviolet rays as well as its antibacterial properties in the shoes of these athletes.

5. Conclusions

The synthesis of selenium nanoparticles by the green method was studied under various factors. The results showed that the quantity and quality of the synthesized nanoparticles are different in different conditions. Based on the results, Allium ampeloprasum extract, due to the high amount of secondary metabolites, mainly phenolic and alkaloid compounds, causes the regeneration of selenium ions and the generation of particles with similar sizes and homogeneous shapes. Although many metal ions dissolved or complexed with other substances can have vital antimicrobial properties, their routine use as antimicrobial agents is limited for reasons such as toxicity to biological systems, but in the case of selenium, due to Its antioxidant and prooxidant properties can be used as an antimicrobial agent or combined with an antimicrobial agent in the chemical form of the element. Biological systems of the element selenium reduced to the degree of oxidation and reduction, while insoluble in water, have fewer biotoxin properties than selenite and selenate ions and other such ions. As a result, it can be used in new antibacterial compounds. This synthesized nanoparticle can produce clothes with ultraviolet ray repellency, and beach volleyball players can protect their skin and body from this radiation's harmful effects. Having antibacterial properties can be used in producing antibacterial shoes for volleyball players.

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