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Nano particles based approaches for Plant and Animal virus detection and diagnosis

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Nano-particle-based approaches for the detection and diagnosis of plant and animal viruses. Nano-particle-based methods offer increased sensitivity, rapid detection, and the ability to detect multiple viral strains simultaneously. In plant virology, various types of nanoparticles have been utilized to enhance the sensitivity and specificity of virus detection assays, enabling real-time monitoring of viral infections in agricultural settings. Similarly, in animal virology, nano-particle-based approaches have shown promising results in the detection of viral diseases in diverse animal species. These approaches offer high sensitivity and specificity, making them valuable tools for surveillance and early detection of viral infections. Overall, nano-particle-based approaches have revolutionized virus detection and diagnosis, and further advancements hold great potential for on-site and point-of-care virus diagnostics.

Keyword: Nano particles, virus detection, plants, animals virology

Introduction

Nanoparticles are particles with dimensions ranging from 1 to 100 nanometers (nm), where one nanometer is equal to one billionth of a meter. They are structures at the nanoscale that exhibit unique physical, chemical, and optical properties compared to their bulk counterparts (Bhagyaraj and Oluwafemi 2018) .

Nanoparticles can be synthesized from various materials, including metals (such as gold, silver, and platinum), semiconductors (such as quantum dots), magnetic materials (such as iron oxide), carbon-based materials (such as graphene and carbon nanotubes), and polymers. These materials can be engineered and manipulated at the nanoscale to achieve specific properties and functionalities (Tsuzuki 2013) .

The small size and large surface area-to-volume ratio of nanoparticles contribute to their distinctive characteristics. Nanoparticles often possess enhanced reactivity, increased surface energy, improved optical properties (such as fluorescence and plasmonic effects), and unique magnetic behavior. These properties make nanoparticles highly suitable for a wide range of applications, including diagnostics, drug delivery, catalysis, sensing, imaging, and environmental remediation (Nayfeh 2016).

Nanoparticles can be functionalized or coated with various molecules, such as antibodies,

aptamers, or specific ligands, to impart targeting capabilities or enhance their interactions with biological systems. Functionalization enables nanoparticles to selectively bind to specific targets, such as viruses, cells, or biomolecules, making them valuable tools in virus detection and diagnosis, among other applications (Singh and Singh 2017).

Gold nanoparticles (AuNPs):

Gold nanoparticles have excellent optical properties, including strong light absorption and scattering, making them suitable for colorimetric-based virus detection. Functionalized AuNPs can undergo aggregation or color changes in the presence of viral targets, enabling visual or spectroscopic detection (Huang, Jain et al. 2007).

Quantum dots (QDs):

Quantum dots are semiconductor nanoparticles with size-tunable emission properties. They exhibit bright and stable fluorescence, allowing for sensitive and multiplexed virus detection. QDs can be functionalized with specific recognition molecules to selectively bind to viral targets (Brkić 2016).

Magnetic nanoparticles (MNPs):

Magnetic nanoparticles possess magnetic properties that enable their manipulation and concentration using external magnetic fields. They are often used in combination with techniques such as magnetic separation or magnetic relaxation for virus detection. MNPs can be functionalized with antibodies or other recognition molecules for specific virus capture and detection (Shubayev, Pisanic II et al. 2009).

Carbon-based nanoparticles:

Carbon-based nanoparticles, such as graphene oxide (GO) and carbon nanotubes (CNTs), have emerged as promising platforms for virus sensing. They possess high surface area, electrical conductivity, and biocompatibility. Functionalized carbon-based nanoparticles can interact with viral targets, leading to changes in electrical or optical signals, enabling sensitive detection (Dizaj, Mennati et al. 2015).

Functionalization of nanoparticles:

Functionalization of nanoparticles involves the modification of their surface with specific molecules or ligands to impart desired properties or functionalities. This process enables nanoparticles to selectively interact with target viruses or biomolecules, enhancing their performance in virus detection and diagnosis.

Antibody conjugation:

Antibodies are widely used to recognize and bind to specific viral antigens. Nanoparticles can be functionalized with antibodies through various conjugation techniques, such as covalent bonding or adsorption. Antibody-conjugated nanoparticles can selectively capture and detect viruses by specifically binding to viral proteins or epitopes (Arruebo, Valladares et al. 2009).

Aptamer functionalization:

Aptamers are short, single-stranded DNA or RNA sequences that can bind to specific targets with high affinity and specificity. Nanoparticles can be functionalized with aptamers, allowing for the selective recognition and capture of viral targets. Aptamer-functionalized nanoparticles offer advantages such as stability, ease of synthesis, and the potential for multiplexed detection (Arruebo, Valladares et al. 2009).

Peptide or protein coating:

Nanoparticles can be coated with peptides or proteins that have affinity for viral targets. The coating can be achieved through physical adsorption or chemical conjugation. Peptide or protein-coated nanoparticles can interact with viral proteins or receptors, enabling specific virus detection and diagnosis (Shemetov, Nabiev et al. 2012).

Small molecule ligands:

Nanoparticles can be functionalized with small molecule ligands that have affinity for viral targets. These ligands can include receptor mimics, enzyme substrates, or specific chemical moieties. Small molecule-functionalized nanoparticles can selectively bind to viral targets, facilitating virus detection and diagnosis (Shemetov, Nabiev et al. 2012).

Different detection techniques employed in nanoparticle-based approaches

Nanoparticle-based approaches for virus detection employ various detection techniques to detect and quantify the presence of viral targets. Here are some commonly used detection techniques in nanoparticle-based virus detection.

Colorimetric detection:

This technique relies on the visual or spectrophotometric changes in the color of

nanoparticles upon interaction with viral targets. (Figure 1). For example, gold nanoparticles can undergo aggregation or produce a color change from red to blue in the presence of viral targets, enabling easy visual detection or measurement using a simple spectrophotometer (Fernandes, Silva et al. 2020).

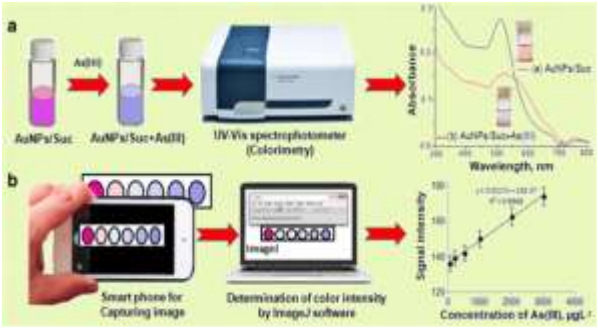

Figure:1 Procedure for Colorometric detection (Shrivas, Patel et al. 2020)

Fluorescence detection: Fluorescence-based detection utilizes the emission of fluorescent signals from nanoparticles upon interaction with viral targets. Quantum dots or fluorescent dye-conjugated nanoparticles can be excited with a specific wavelength of light, and the emitted fluorescence can be measured using fluorescence spectroscopy or imaging techniques. The intensity of fluorescence indicates the presence and concentration of the viral targets (Fernandes, Silva et al. 2020).

Surface-enhanced Raman scattering (SERS): SERS is a highly sensitive detection technique that relies on the enhancement of Raman signals by nanoparticles. Nanoparticles with unique surface properties, such as gold or silver nanoparticles, can amplify Raman signals from nearby molecules, including viral targets. By detecting the enhanced Raman scattering signals, the presence and identification of viruses can be achieved (Zhang, Zhao et al. 2017).

Magnetic detection: Magnetic nanoparticles can be employed in magnetic-based detection methods. These nanoparticles can be functionalized with viral-specific ligands or antibodies and used to capture viral targets from a sample. The captured nanoparticles can then be separated and concentrated using magnetic fields, and the presence of viral targets can be determined using techniques like PCR, ELISA, or biosensors (Zhang, Zhao et al. 2017).

Sensitivity, specificity, and reliability of these methods compared to traditional techniques.

Sensitivity: Nanoparticle-based approaches can provide higher sensitivity in virus detection due to the unique properties of nanoparticles. For instance, functionalized nanoparticles can exhibit enhanced signal amplification, allowing for the detection of low concentrations of viral targets. Additionally, nanoparticles with large surface areas provide more binding sites, increasing the probability of capturing viral targets. Compared to traditional techniques, such as serological assays or microscopy, nanoparticle-based methods often offer greater sensitivity, enabling the detection of viruses at lower concentrations (Draz and Shafiee 2018).

Specificity: Functionalization of nanoparticles with specific ligands, antibodies, or aptamers enables target-specific recognition and binding. This enhances the specificity of nanoparticle-based approaches by reducing the chances of false-positive results. Traditional techniques, such as serological assays, may have cross-reactivity issues, leading to false-positive or false-negative results. Nanoparticle-based methods can overcome these limitations and provide higher specificity in virus detection (Koedrith, Thasiphu et al. 2015).

Reliability: Nanoparticle-based approaches can offer improved reliability by reducing the chances of operator-dependent errors and variability. These methods often involve standardized protocols and readout methods, ensuring consistent and reproducible results. In contrast, traditional techniques like PCR can be prone to contamination or technical errors, leading to unreliable results. Nanoparticle-based methods can provide more reliable and robust virus detection by minimizing potential sources of variability (Gualerzi, Picciolini et al. 2021).

Speed and efficiency: Many nanoparticle-based approaches offer relatively rapid detection times compared to traditional techniques. For example, some colorimetric or fluorescence-based methods can provide results within minutes to hours, enabling real-time or point-of-care testing. Traditional techniques such as cell culture or PCR usually require longer processing times and complex procedures. The faster turnaround time of nanoparticle-based methods enhances their efficiency and utility in various settings (Siangproh, Dungchai et al. 2011).

Multiplexing capability: Nanoparticle-based approaches often allow for multiplexed detection, wherein multiple viral targets can be simultaneously detected in a single assay. This capability is particularly advantageous in situations where multiple viruses need to be

identified or when screening for a panel of viral strains. Traditional techniques may require separate assays for each target, resulting in increased time and cost. Nanoparticle-based methods enable efficient multiplexed detection, saving time and resources (Leng, Sun et al. 2015)

Emerging trends and future directions in nanoparticle-based virus detection and diagnosis.

Nanoparticle-based virus detection and diagnosis continue to be an active area of research, and several emerging trends and future directions are shaping the field.

Point-of-care testing (POCT):

There is a growing focus on developing nanoparticle-based virus detection assays that can be performed at the point of care, such as clinics, field settings, or resource-limited areas. These assays aim to provide rapid, portable, and user-friendly diagnostic tools that can deliver real-time results, enabling timely treatment and containment strategies (Soh, Chan et al. 2020).

Paper-based and lateral flow devices:

Researchers are exploring the integration of nanoparticles into paper-based or lateral flow devices for virus detection. These devices offer simplicity, low cost, and ease of use. Nanoparticles can be employed as labels or signal amplifiers in these devices, enabling visual or colorimetric detection of viral targets. This technology has the potential for widespread deployment in resource-limited settings (Nguyen, Song et al. 2020).

Biosensors and microfluidic platforms:

Nanoparticles are being incorporated into biosensor and microfluidic platforms to enable highly sensitive and selective virus detection (Figure 2). These platforms can integrate multiple functions, such as sample preparation, analyte capture, and signal transduction, into a single device, providing miniaturized and automated systems for virus diagnosis. Nanoparticles with unique optical, magnetic, or electrochemical properties are being explored for enhanced sensing capabilities in these platforms (Jauset-Rubio, Svobodová et al. 2016).

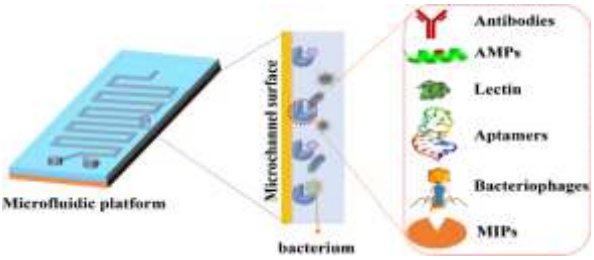

Figure: 2. Advances in Microfludic platform (Mi, Hu et al. 2022)

Multiplexed detection and high-throughput screening:

Efforts are underway to develop nanoparticle-based assays capable of simultaneously detecting multiple viral targets. Multiplexed detection allows for efficient screening and identification of different viruses or strains in a single assay, saving time and resources. High-throughput screening approaches using nanotechnology are also being explored to analyze large numbers of samples rapidly, enabling efficient surveillance and monitoring (Leng, Sun et al. 2015).

Advanced imaging and spectroscopy techniques:

Nanoparticles with engineered optical properties are being utilized in advanced imaging and spectroscopy techniques for virus detection. For example, plasmonic nanoparticles can provide enhanced contrast and sensitivity in imaging modalities such as photoacoustic imaging or surface-enhanced Raman scattering (SERS). These techniques enable noninvasive and label-free visualization or characterization of viruses in complex biological samples (Maddali, Miles et al. 2021).

Smart nanomaterials and stimuli-responsive systems:

Researchers are exploring the development of smart nanomaterials and stimuli-responsive systems for virus detection. These materials can undergo controlled changes in their properties, such as size, shape, or fluorescence, in response to specific stimuli or viral interactions. Such systems enable real-time monitoring and enhanced signal generation in virus detection assays (Lukose, Chidangil et al. 2021).

CONCLUSION

Future Perspective and Goals

The goals and future perspectives in nanoparticle-based virus detection and diagnosis

encompass enhancing sensitivity and specificity, enabling multiplexed and high-throughput detection, advancing point-of-care and decentralized testing, integrating with digital health technologies, exploring nanoparticles for therapeutics and vaccine delivery, addressing safety and regulatory considerations, and fostering collaboration and interdisciplinary research. These endeavors aim to improve the accuracy, speed, portability, and accessibility of virus detection, facilitating early diagnosis, effective treatment, and surveillance of viral infections for improved public health outcomes.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

M Sikandar, & Jamal Kazam conceived the idea, S Alam and Z Ahmad made corrections, A Andleeb and F Tahir proof read the final draft. : M Sikandar, M Sikandar, Wrote the initial draft of paper and handle the correspondence. U Farooq, H Ali and U Saleem analyzed the data

REFERENCES

Arruebo, M., et al. (2009). "Antibody-conjugated nanoparticles for biomedical applications." Journal of Nanomaterials 2009: 1-24.

Bhagyaraj, S. M. and O. S. Oluwafemi (2018). Nanotechnology: the science of the invisible. Synthesis of inorganic nanomaterials, Elsevier: 1-18.

Brkić, S. (2016). "Optical properties of quantum dots." Eur Int J Sci Technol 5(9): 98-107.

Dizaj, S. M., et al. (2015). "Antimicrobial activity of carbon-based nanoparticles." Advanced pharmaceutical bulletin 5(1): 19.

Draz, M. S. and H. Shafiee (2018). "Applications of gold nanoparticles in virus detection." Theranostics 8(7): 1985.

Fernandes, G. M., et al. (2020). "Novel approaches for colorimetric measurements in analytical chemistry–A review." Analytica Chimica Acta 1135: 187-203.

Gualerzi, A., et al. (2021). "Biophotonics for diagnostic detection of extracellular vesicles." Advanced drug delivery reviews 174: 229-249.

Huang, X., et al. (2007). "Gold nanoparticles: interesting optical properties and recent applications in cancer diagnostics and therapy."

Jauset-Rubio, M., et al. (2016). "Ultrasensitive, rapid and inexpensive detection of DNA using paper based lateral flow assay." Scientific reports 6(1): 37732.

Koedrith, P., et al. (2015). "Recent trends in rapid environmental monitoring of pathogens and toxicants: potential of nanoparticle-based biosensor and applications." The Scientific World Journal 2015.

Leng, Y., et al. (2015). "Suspension arrays based on nanoparticle-encoded microspheres for high-throughput multiplexed detection." Chemical Society Reviews 44(15): 5552-5595.

Lukose, J., et al. (2021). "Optical technologies for the detection of viruses like COVID-19: Progress and prospects." Biosensors and Bioelectronics 178: 113004.

Maddali, H., et al. (2021). "Optical biosensors for virus detection: prospects for SARS-CoV-2/COVID-19." ChemBioChem 22(7): 1176-1189.

Mi, F., et al. (2022). "Recent advancements in microfluidic chip biosensor detection of foodborne pathogenic bacteria: a review." Analytical and Bioanalytical Chemistry 414(9): 2883-2902.

Nayfeh, M. H. (2016). "Optics in nanotechnology." Optics in Our Time: 223-264.

Nguyen, V.-T., et al. (2020). "Recent advances in high-sensitivity detection methods for paper-based lateral-flow assay." Biosensors and Bioelectronics 152: 112015.

Shemetov, A. A., et al. (2012). "Molecular interaction of proteins and peptides with nanoparticles." ACS nano 6(6): 4585-4602.

Shrivas, K., et al. (2020). "Colorimetric and smartphone-integrated paper device for on-site determination of arsenic (III) using

sucrose modified gold nanoparticles as a nanoprobe." Mikrochim Acta 187(3): 173.
Shubayev, V. I., et al. (2009). "Magnetic nanoparticles for theragnostics." Advanced drug delivery reviews 61(6): 467-477.
Siangproh, W., et al. (2011). "Nanoparticle-based electrochemical detection in conventional and miniaturized systems and their bioanalytical applications: A review." Analytica Chimica Acta 690(1): 10-25.
Singh, M. and C. Singh (2017). "Characterization of nano particles by using major tools and techniques." applications of nanotechnology an introduction: 57.
Soh, J. H., et al. (2020). "Strategies for developing sensitive and specific nanoparticle-based lateral flow assays as point-of-care diagnostic device." Nano Today 30: 100831.
Tsuzuki, T. (2013). "Properties of Nanoparticulate Materials." Nanotechnology Commercialization: 1.
Zhang, Y., et al. (2017). "Surface-enhanced Raman spectroscopy (SERS) combined techniques for high-performance detection and characterization." TrAC Trends in Analytical Chemistry 90: 1-13.