ISSN: 2792-0666

NanoEra

Volume: 2
Issue : 1

2022

Journal Name: NanoEra

ISSN: 2792-0666

Managing Office:
Nanoscience and Nanoengineering Research and Application Center, Atatürk University

Website: dergipark.org.tr/nanoera

e-mail: nanoera@atauni.edu.tr

Publication Language: English

Publication Type: International Journal

Published Online: June, 2022

Publisher: Atatürk University Press

Owner on Behalf of Atatürk University
Prof. Ömer ÇOMAKLI (Rector)

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The Nanoera journal is published biannually by Atatürk University, Nanoscience and Nanoengineering Research and Application Center, Erzurum / TURKEY.

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Scope

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ISSN: 2792-0666

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RESEARCH ARTICLE

Comparative study of single-slot and multi-slot graphene-based microstrip patch antenna for X-band application

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HIGHLIGHTS

> Microstrip patch antenna was designed and simulated using Duroid as a substrate with graphene as a conductive patch material. Four different models were designed and simulated with different slots which includes 1,2 3 and without slot of different dimensions. The single-slot based antenna showed better performance in terms of gain and bandwidth. The antenna can be used for X-band applications.

ARTICLE INFO

Received : 06 November 2021
Accepted : 01 April 2022
Published : 09 June 2022

***Keywords*:**
Graphene
X-Band
Slots

ABSTRACT

Microstrip patch antennas can be made from a variety of materials with varying dielectric constants. In this article, a modified multi-slot patch multiband antenna is simulated using CST. Graphene is proposed as a patch material for an antenna that is designed to be used and studied at X and Ku band frequencies. Because of graphene's high conductivity, it is appealing to use it as a conductive patch material to replace copper and other metal conductors while also increasing the antenna's bandwidth and radiation efficiency. On the patch, different sized slot cuts were made. The antenna is made of Duroid RT5880 (lossy) material with a dielectric constant of 2.2 that is sandwiched between a graphene patch and a ground plane. The antenna resonated at 11.22 GHz, indicating that it could be used in the X band frequency range.

1. Introduction

Microstrip patch antennas (MPA) were introduced in the 1950s and quickly became one of the most rapidly evolving devices in radio frequency engineering. This is due to communications' rapid advancement [1,2]. The advantages that made the microstrip radio wire noticeable are that it is moderately simple to construct, reasonable, lightweight, and has a slim bulge from the surface. These MPAs have well-known frequencies that exceed 100 MHz. The receiving wire for the fix is made on a dielectric substrate [3]. Nanotechnology is a cutting-edge method of technological advancement that involves the management of material at the nanoscale (1 billion times smaller than a meter) [4]. Nanotechnology truly encompasses the creation and application of chemical, physical, and organic frameworks at scales ranging from single particles or molecules to submicron levels, as well as their integration into larger frameworks to form nanomaterials [5]. Nanomaterials are materials with a thickness of less than 100 nanometers. Nanomaterials, such as graphene, frequently fall into different dimensional categories, such as 2D, 1D, or 0D [6].

Graphene is rapidly becoming an extremely appealing material for a wide range of electronic components, circuits, systems, and devices, including frequency multipliers, metamaterials, organic electronics, high frequency field effect transistors (FET), wireless nano-sensors, modulators, transparent solar cells, and terahertz devices [7]. It has excellent performance with much lower power consumption, as well as the option of fabricating it using advanced silicon device (CMOS) fabrication technology [1,2].

Enhancing bandwidth is a critical requirement for the practical application of microstrip patch antennas [8]. Bandwidth enhancement techniques include using a material with a lower dielectric constant, partial grounding, creating and/or enlarging the antenna's inset gap, and utilizing the defective ground structure (DGS) [7,9]. Adjacent slots were introduced to the patch in this paper, significantly increasing the antenna bandwidth. The X-Band frequency range, as

Cite this article: Yunusa, Z; Shehu, A. A.; Comparative study of single-slot and multi-slot graphene-based microstrip patch antenna for X-band application. *NanoEra* 2(1), 1–4

defined by IEEE Standard in 2002, ranges from 8 to 12 GHz. This frequency range is widely used in radar applications, air traffic control, military satellite, weather forecasting and monitoring, radio-determination purposes, defense, and law enforcement vehicle speed tracking [10].

2. Methodology

The antenna is designed using the standard design equations [3]. Table 1 summarizes and presents the design parameters. Figures 1–4 show the antenna being simulated in CST design studio. Figure 1 depicts a conventional rectangular antenna, while Figure 2 depicts an MPA with a single rectangular slot cut at the top right hand corner of size 1mm by 4mm. Figure 3 depicts the MPA with two rectangular slots on the top right and bottom left sides. Figure 4 depicts the MPA with three rectangular slots, the third of which is cut in the patch element's center.

Table 1. Design parameters of the Antenna

S/No.	*Parameters*	*Dimension (mm)*
1	Substrate width	21
2	Substrate length	19
3	Patch width	12
4	Patch length	9
5	Feedline width	6
6	Feedline length	3
7	Slot width	4
8	Slot length	1
9	Substrate thickness	1.57
10	Ground/Patch thickness	0.02

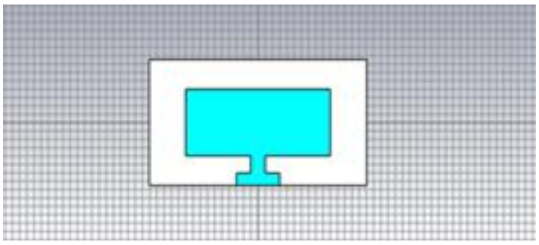

Figure 1. Conventional MPA

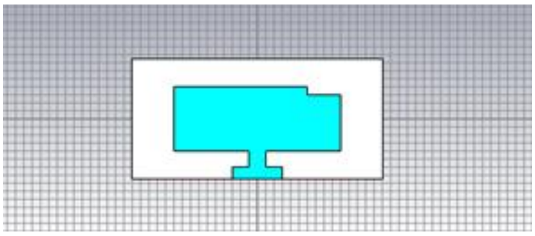

Figure 2. MPA with 1 rectangular slot

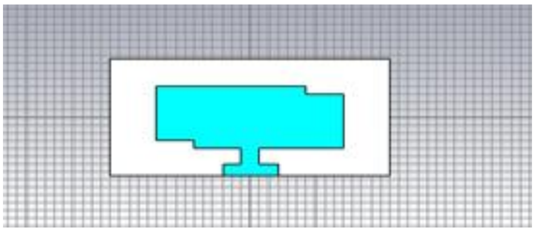

Figure 3. MPA with 2 rectangular slots

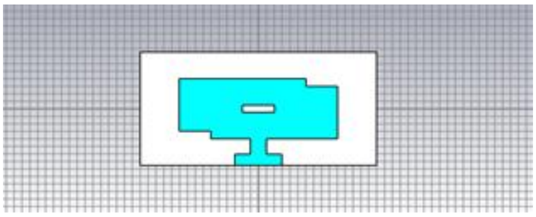

Figure 4. MPA with 3 rectangular slots

3. Results and Discussion

Standing waves occur when antenna matching is poor, resulting in the power applied to the antenna being reflected rather than emitted. Figure 5 depicts the S11 results for the various models, and Table 2 displays the values. A properly impedance matched antenna has a VSWR of 1:1. The frequency range over which an antenna can operate is referred to as its bandwidth. Figure 5 depicts the various bandwidths obtained from various designs, and the values are shown in Table 2. Figure 7 depicts a plot of VSWR for all of the models that returned a value between 1 and 2. Antenna gain is a measurement of the directivity and efficiency of an antenna. It is defined as the ratio of the peak intensity direction radiation intensity to the intensity that would be obtained if the antenna's power was radiated isotropically. Figure 8 also shows the antenna gain, and the numbers are summed and reported in Table 2. According to the results, the antenna with one slot performed better in terms of gain, directivity, and bandwidth. This demonstrates that a single slot improves antenna performance over several slots.

The narrow bandwidth and poor gain of microstrip patch antennas (MPA) are two key drawbacks. Due to their exposure to high pressure and external temperature changes, the latest wireless communication systems require operation in a variety of situations and operation bands (X band in this study). The risk of copper failure and other metal materials due to recurring bending, temperature stability, corrosion resistance, and deformations is another downside of employing a traditional copper conducting material antenna [9]. Other positive features that make graphene, as a nanomaterial, the latest trendy material in the creation of newest gadgets are that it conducts a lot of electricity in a tiny space, which allows for the development of miniaturized devices and super-fast machines that use very little power [4,8]. The use of graphene patch as a conducting material in a microstrip patch antenna is regarded to have extraordinary potential in terms of increasing antenna bandwidth and radiation efficiency due to its outstanding electromagnetic properties and functionalities. A graphene plane also provides strong shielding against microwave radiation due to its high electrical conductivity. The use of graphene as a conductive patch material has also demonstrated that it may be a viable alternative to utilizing metal conductors.

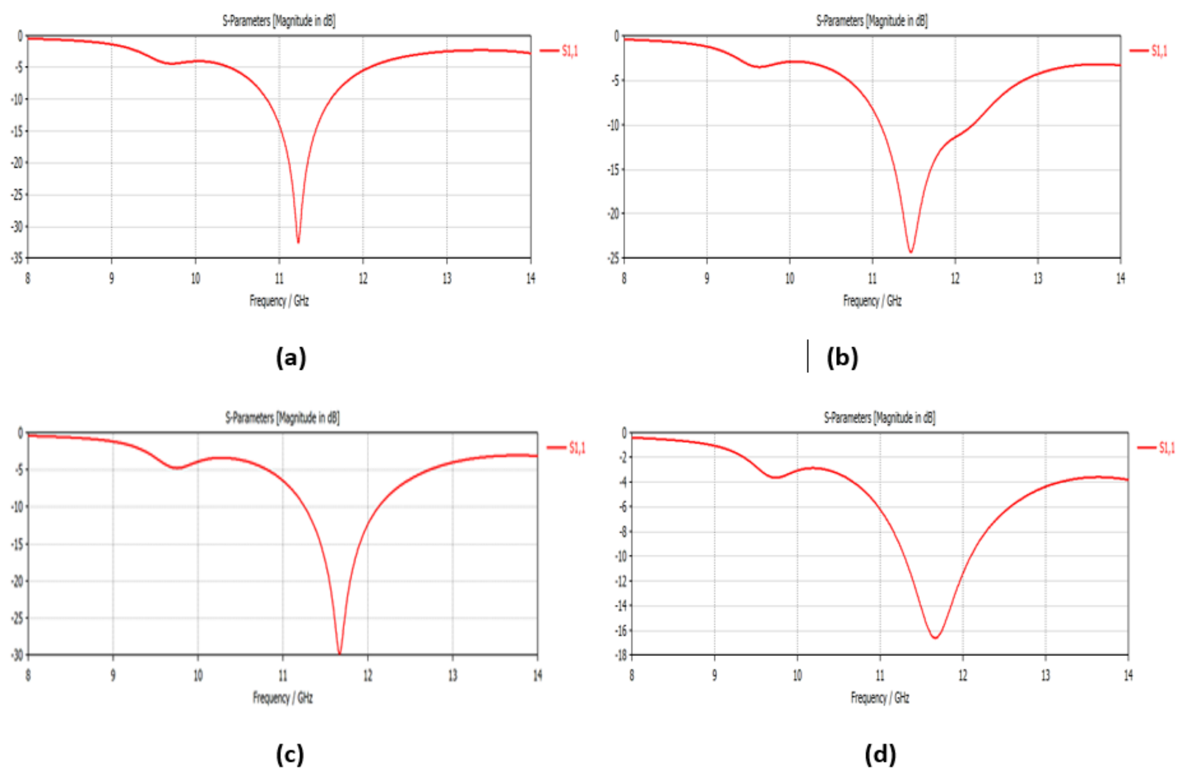

Figure 5. Bandwidth result showing (a) model 1, (b) model 2 (c) model 3 (d) model 4

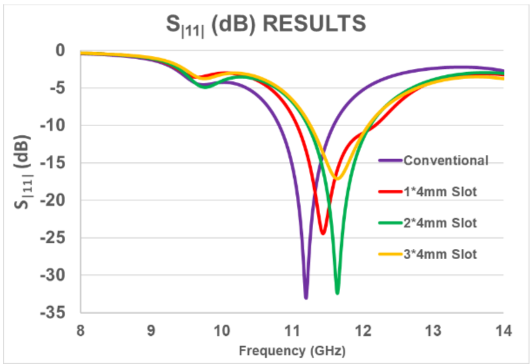

Figure 6. $S_{|11|}$ results

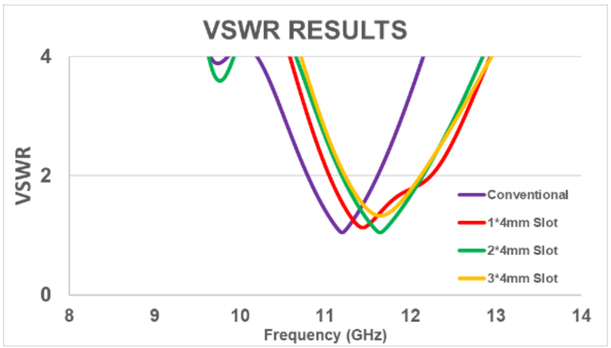

Figure 7. VSWR results

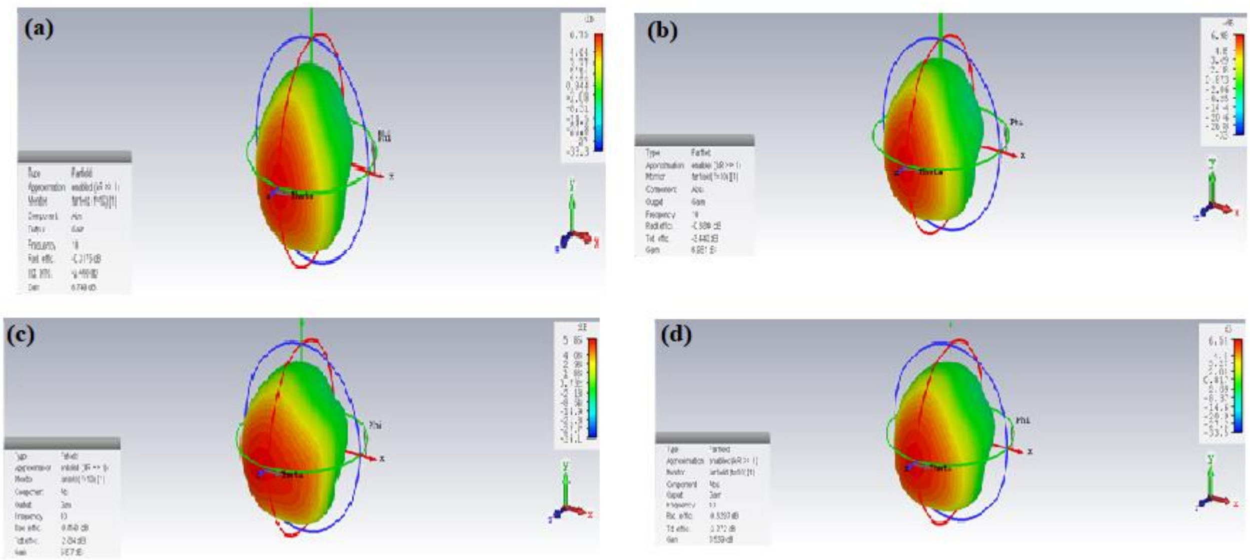

Figure 8. Gain result showing (a) model 1, (b) model 2 (c) model 3 (d) model 4

Table 2. Summary of Results

No.	Model	S11	VSWR	Rf (GHz)	Gain (Db)	Directivity (Dbi)	BW (MHz)
1	Conventional	-25.4	1.04	11.22	6.75	7.07	770
2	1mm by 4mm slot	-24.54	1.13	11.46	6.98	7.32	1114
3	2*1mm by 4mm slots	-35.56	1.03	11.69	5.86	6.17	896
4	3*1mm by 4mm slots	-16.72	1.34	11.64	6.54	6.87	814

4. Conclusion

The designed antenna performs well in terms of bandwidth and operates in the X band. The frequency ranges specified can be used for military satellites, military and government institutions for weather monitoring, air traffic control, defense and tracking vehicle speed detection for law enforcement, and the aerospace industry, where low weight, mechanical durability, and temperature independence are critical.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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NanoEra

ISSN: 2792-0666

https://dergipark.org.tr/nanoera

RESEARCH ARTICLE

Effect of nitrogen doping amount on the activity of commercial electrocatalyst used in PEM fuel cells

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HIGHLIGHTS

> Nitrogen doping was achieved on a commercial catalyst.
> Nitrogen to catalyst ratio was changed.
> Changing nitrogen amount altered contact angle and PEM fuel cell performance.

ARTICLE INFO

Received : 08 April 2022
Accepted : 04 June 2022
Published : 09 June 2022

Keywords:
Nitrogen Doping
Melamine
N-doped Catalyst
Contact Angle
PEM Fuel Cell

ABSTRACT

The amount of nitrogen doping has attracted attention recently because it provides additional catalytically active sites in catalysts. In this study, nitrogen-doped (N-doped) catalysts were synthesized by mixing melamine as a nitrogen source and commercial Tanaka catalyst with 67% Pt loading in different amounts of melamine. After nitrogen doping, N-doped catalysts were characterized by FTIR, XRD, elemental analysis, contact angle measurement, and PEM fuel cell performance tests. Change in the nitrogen amount in the catalyst resulted in an increase in the PEM fuel cell performance which can be attributed to the significant change in contact angle and so in the hydrophobicity of the catalysts.

1. Introduction

The Proton exchange membrane (PEM) fuel cell has received great attention due to its power efficiency, non-hazardous waste, and moderate operating conditions. Various conditions are needed to achieve high performance, such as efficient use of platinum, conductive support, and an active catalyst. In addition to all these conditions, the commercialization of the PEM fuel cell is hindered at a high cost due to the use of platinum and unstable catalysts. Many researchers have tried to reduce the amount of platinum by developing non-platinum metal catalysts or by improving durable catalysts and the electrochemical activity of platinum. Mostly, carbon-supported platinum catalysts are used as catalysts, but these catalysts have some problems such as dissolution and agglomeration of platinum [1–5].

Some researchers have tried to increase its effectiveness by modifying the supplement material, either in-situ or ex-situ [6]. Different elements such as nitrogen, boron, fluor, and sulfur are used as additives. Nitrogen is a commonly used additive. Various chemical compounds such as melamine, pyrrole, aniline, 1,10 phenanthroline, dicyanamide, ethylenediamine, and phthalocyanine are used as nitrogen sources. Supporting nitrogen-functionalized carbon was also of interest because functionalization with nitrogen resulted in avoiding the existing 3D morphology, which facilitates aggregation and the porous channel that allows the mass transfer. Due to the increased potential of these catalysts and obtaining durable catalysts, some researchers have studied this phenomenon recently [7].

Both Pt-alloyed and nitrogen-doped hybrid supports have been studied in the literature. Reduced graphene oxide and multi-walled carbon nanotube (MWCNT) were used as hybrid support and pyrrole was used as a nitrogen source. The prepared nitrogen-containing hybrid support was annealed at 800 °C for 3 hours under an argon atmosphere. The Pt alloy was reduced compared to the hybrid support and

Cite this article: Özcelik N.; Bayrakceken Yurtcan, A.; Effect of nitrogen doping amount on the activity of commercial electrocatalyst used in PEM fuel cells. *NanoEra* 2(1), 5–9

when all the performance results were examined, it was seen that the nitrogen-doped reinforced $PtFe_3$ had the best performance compared to $PtCo_3$ and Pt/C. These may be due to the nitrogen content in the hybrid support and the high dispersion of the alloys [8].

Nitrogen-doped graphene nanoplatelets (N-G) were prepared in situ using NH_3 as a nitrogen source. Then, the obtained support was used and Pt nanoparticles were reduced on it. Finally, the fuel cell performance of the prepared electrocatalyst was measured. After measurements, the maximum power densities of N-G and Pt/G were 440 mW/cm^2 and 390 mW/cm^2, respectively. This difference is due to the decomposition of the intermediate of oxygen reduction reaction (ORR) by the anchor side, high conductivity, and nitrogen doping [9].

Graphene, CNT, or different ratios of Graphene and CNT were initially mixed with the ionic liquid of 1-ethyl-3-methylimidazolium dicyanamide and then pyrolyzed at 600°C for 1 minute. The fuel cell performance of the obtained electrocatalysts showed that Pt@G/N-CNT had the best current density at 0.65 V among all electrocatalysts [10].

Another study was conducted with Pt/C and ethylenediamine. Ethylenediamine was fixed on Pt/C by reflux for 8 hours at 75 °C. Thus, the catalyst was coated with ethylenediamine at a thickness of 1 nm. After the anchoring process, the prepared catalyst was annealed and the annealing temperature was optimized by changing the temperature between 400 and 700 °C with an increase of 100 °C. It was understood that the nitrogen doping of carbon atoms causes an increase in electronegativity and this facilitates the adsorption of oxygen molecules. The available densities of the catalysts were 1804, 1788, 1555, 1521, and 1280 mA/cm^2 for the Pt/C catalyst with annealing temperatures of 400, 500, 600, and 700 °C [11].

Commercial catalyst (Pt/C) was also functionalized with aniline. For this purpose, the aniline monomer was polymerized with ammonium persulfate and the resulting catalyst contains nitrogen. The performance result showed that the durability of the nitrogen-doped catalyst was higher than that of Pt/C [12].

In another study, a platinum and aniline complex was obtained in an inert medium and then heated at 500 °C for 2 hours in a nitrogen atmosphere. The authors noticed that after performance measurements, Pt/C outperformed the prepared catalyst. The reason for the decrease in the performance of the prepared catalyst was attributed to the difference between the Pt/C thicknesses and the 5 μm and 50 μm values of the prepared catalyst, respectively. However, the authors showed that the prepared catalyst had better durability than Pt/C due to the carbonized aniline shell protecting them from platinum agglomeration and Ostwald ripening [13].

Nitrogen-doped CNT (N-CNT) was first prepared by chemical vapor deposition method and ethylenediamine and pyridine were used as nitrogen sources. They showed that N-CNTs synthesized with nitrogen-rich ethylenediamine showed superior catalytic activity for the ORR [14].

The sandwich structure of Pt-CNT was first prepared by annealing under ammonia gas, then the Pt NPs were reduced and the second nitrogen layer was coated by mixing the prepared Pt/N-CNT and PVP, then annealed under a nitrogen atmosphere at 500 °C for 2 hours. The maximum power densities of the prepared catalysts are 676, 539, 376 mW/cm^2 for the Pt-CNT, N-CNT, and Pt/Carbon black sandwich structures, respectively. This difference may be due to the nitrogen-doped carbon layer, which contributes to the adsorption and desorption of oxygen species on the Pt surface [15].

Jung et al. studied nitrogen-doped carbon-supported Pt and PtCo catalysts and the results showed that the hybrid supports performed better than Pt/C after accelerated stress tests of the prepared catalysts [16–18].

In this work, commercially available Pt/C catalyst was doped with nitrogen using melamine as the nitrogen source. The catalyst-melamine ratios were varied to determine the effect of different nitrogen doping levels on the properties of the catalysts. The catalysts were characterized using FT-IR, XRD, and contact angle measurements. Elemental analysis was used to determine the nitrogen content. PEM fuel cell performance tests were conducted to find the catalyst with the best fuel cell performance.

2. Experimental

2.1. Synthesis of nitrogen-doped Pt/C

In order to dope nitrogen over commercial Pt/C (Tanaka, 67 %) catalysts, melamine was used as a nitrogen source. The required amounts of the catalyst and melamine depending on the targeted ratios were grained mechanically in mortar having the catalyst to melamine ratios of 1:1, 4:1, 8:1 for 10 min. After mixing, the prepared mixture was annealed at 900 °C for 1 h under a nitrogen atmosphere as shown in Figure 1.

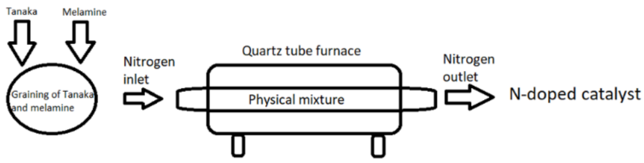

Figure 1. Representative synthesis scheme

2.2. Characterization

2.2.1. Physical characterization of Nitrogen-doped Pt/C

The nitrogen-doped catalysts were characterized by using FT-IR, XRD, contact angle measurement, and PEM fuel cell performance tests. Functional groups over the catalysts were investigated by using Fourier transform infrared spectroscopy (FT-IR) with Perkin Elmer Spectrum One. In order to identify crystal structure, XRD data were obtained by a Rigaku Miniflex X-ray diffractometer. The diffractometer with a CuK_α (λ = 1.5406 Å) radiation source was operated in continuous scan mode at a scan rate of 0.6 ° min^{-1} in the range of 10 – 90 ° (2θ). In order to determine the hydrophobic character of the prepared catalysts, we measured contact angle at room temperature with Attension Theta Optic Tensiometer & Topography. The nitrogen amount over the catalysts was determined by the AFK-5 elemental analysis instrument.

2.2.2. Membrane electrode assembly (MEA) preparation and fuel cell testing

In order to characterize the electrochemical activities of the prepared catalysts, in-situ PEM fuel cell performance tests were performed with a single fuel cell hardware. For the cell performance test, the membrane electrode assemblies (MEAs) were prepared by brushing catalyst ink (including definite amounts of catalyst, 2-propanol (Sigma Aldrich), and Nafion solution) onto gas diffusion layers (GDLs). The platinum loading over the electrode was set to 0.4 mg Pt cm^{-2}. Then, a five-layer MEA was prepared by pressing these GDLs onto the Nafion 212 membrane at 130 °C, 400 psi for 4 min in order to create a good interfacial contact between the GDL and the catalyst layer. The geometric area of the electrode was 4.41 cm^2. A commercially available PEM fuel cell hardware (Electrochem) and fuel cell test station (Henatech) were used for the experiments. During the experiments, the temperature of the single-cell was maintained at 70 °C, and fully humidified hydrogen/oxygen gases were fed into the anode/cathode at 70 °C at flow rates of 250 ml/min.

3. Results and Discussion

The XRD patterns are shown in Figure 2 exhibit the representative diffraction peaks at 39.8°, 46.3°, 68.2°, and 81.6°. They indicated that all the broad diffraction peaks of the XRD patterns at 2θ = 39.6, 47.4, and 67.1° corresponding to the reflections of (111), (200), (220), respectively, which are consistent with the face-centered cubic (fcc) structure of platinum (Pt) which can be assigned to (JCPDS Card 04-0802), thus demonstrating the presence of crystalline Pt.

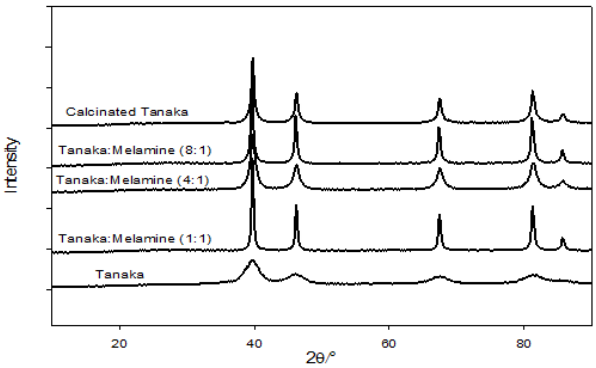

Figure 2. XRD patterns of the prepared catalysts

This indicates the presence of platinum in the catalysts. Characteristic peaks of Tanaka-Melamine (4:1) catalyst are significantly sharper than Tanaka catalyst due to the crystallite size effect. Scherer equation was used to calculate the particle sizes of the Pt nanoparticles by using the (110) plane from XRD data (Table 1).

Table 1. Particle sizes calculated from the Scherer equation

Catalyst name	Particle size (nm)
Tanaka	3.01
Tanaka: Melamine (1:1)	3.26
Tanaka: Melamine (4:1)	2.96
Tanaka: Melamine (8:1)	3.13
Calcinated Tanaka	3.85

Pt particle sizes were increased with heat treatment. The Scherrer equation (Equation 1) is given below where, L = average crystal size (angstrom or nm); B = the full-width half maximum of the peak; K = the Scherrer constant; depends on the how the width is determined, the shape of the crystal, and the size distribution; λ = the wavelength of the radiation used to collect the data.

$$L = \frac{0.9\lambda}{B\cos\theta} \quad (1)$$

Figure 3 exhibits the IR spectrums of the catalysts. The band located at nearly 1600 - 1650 cm^{-1} can be attributed to the C=C group [19,20]. The small peak located at around 1750 cm^{-1} is assigned to C=O (carbonyl) stretching vibration [19]. As can be seen from Figure 3, a broad N-H stretching absorption band is located between 3200-3600 cm^{-1} [19]. The band located at nearly 2800-2950 cm^{-1} can be attributed to C-H [20].

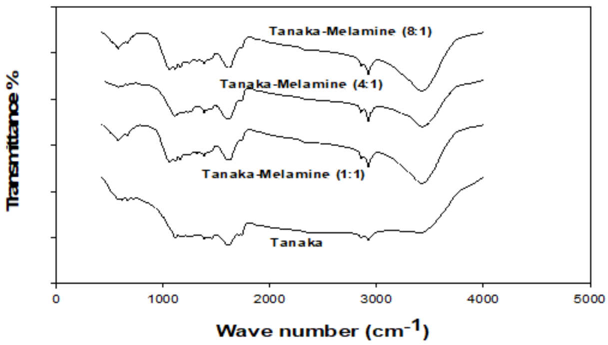

Figure 3. FT-IR spectrum of the prepared catalysts

Elemental analysis is used to determine which element is present in the structure (Table 2). In this study, we tried to dope nitrogen and used it to evaluate nitrogen amount with elemental analysis. Nitrogen amounts were determined by using elemental analysis. The amount of nitrogen increased as the amount of melamine increased and a very small amount that could not able to be detected with elemental analysis was obtained for the catalyst having the least melamine amount [10].

Table 2. Nitrogen contents of the prepared catalysts with elemental analysis

Catalyst name	Nitrogen amount (% wt.)
Tanaka-Melamine (1:1)	0.109
Tanaka-Melamine (4:1)	0.291
Tanaka-Melamine (8:1)	0.078

Contact angle value is a scale of surface wetting property and materials' hydrophobicity. The tangent angle value of any liquid droplet according to the solid surface baseline is called contact angle. The contact angle measurements were taken at room temperature (Figure 4) and are tabulated in Table 3. All the catalysts showed the hydrophobic characteristics but an increase in the nitrogen doping amount increased the contact angle values and so the hydrophobicity. An increase in contact angle is needed for better (ORR) activity because it makes it easy to remove water that forms during the ORR process. But an increase in hydrophobicity must be at a particular level and if the contact angle is above particular hydrophobicity, increasing in hydrophobicity leads to a decrease in PEM fuel cell performance [21].

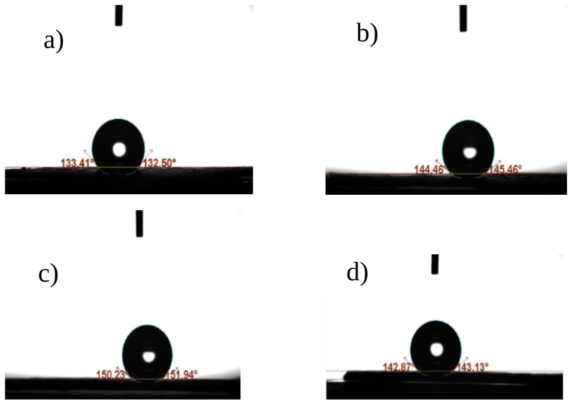

Figure 4. Contact angle measurement of the prepared catalysts a) Tanaka b) Tanaka-Melamine (4:1) c) Tanaka-Melamine (1:1) d) Tanaka-Melamine (8:1) at room temperature

Table 3. Contact angles of the prepared catalysts

Catalyst name	Contact angle
Tanaka	132.9 °
Tanaka: Melamine (1:1)	144.9 °
Tanaka: Melamine (4:1)	151.1 °
Tanaka: Melamine (8:1)	143.0 °

The performance of the PEM fuel cell is evaluated according to the typical polarization curve in which cell potential is plotted versus current density. Some degradation mechanisms occur while the cell operates so the voltage drops are seen beginning from the open-circuit voltage (OCV) to lower values along with increasing current drawn from the fuel cell. The liquid water level in the cell must be balanced for stable operation due to considerable performance loss in the event of flooding. Performances of the electrocatalysts consisting of different catalyst to melamine ratios were measured and the highest performance depending on nitrogen doping level is investigated (Figure 5). It was observed that Tanaka-Melamine (4:1) exhibited the highest current density up to higher current density values. But the further increase in the current density resulted in a decrease in the performance. From this extent of current density, Tanaka showed better performance. Calcined Tanaka catalyst which has the biggest particle size showed the worst performance result [11]. All the catalysts containing nitrogen showed concentration polarization although they had higher contact angles. These results showed that there has to be an optimum value for nitrogen doping and also contact angles.

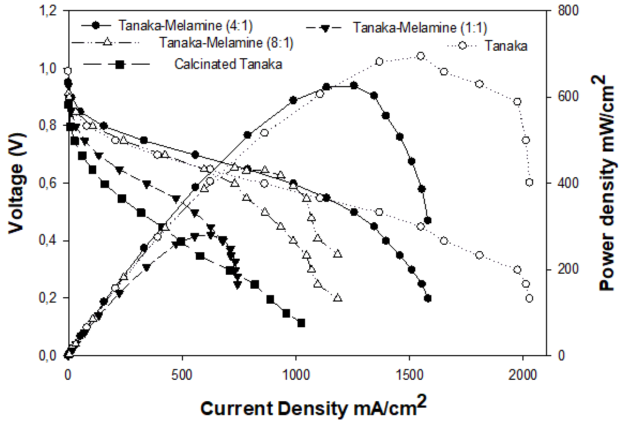

Figure 5. Polarization curve of the prepared catalysts

4. Conclusions

N-doped commercial catalysts via pyrolysis under a nitrogen atmosphere were synthesized and melamine was used as a nitrogen source due to its high nitrogen content. Nitrogen-doped catalysts were obtained and the change in the catalysts depending on the nitrogen amount is examined. When melamine was added, it was realized that contact angles differ from each catalyst significantly. It was shown that the amount of nitrogen in the catalysts has a significant impact on PEM fuel cell performance which needs to be optimized further.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

Acknowledgment

The authors thank the East Anatolia High Technology Application and Research Center (DAYTAM) for the characterizations.

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NanoEra 2(1), 10-13

NanoEra

ISSN: 2792-0666

https://dergipark.org.tr/nanoera

REVIEW ARTICLE

Application of nanotechnology in animal nutrition

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HIGHLIGHTS

> This review article aims to gather the materials and research that has been done to clarify the potential effects of nanotechnology on animal nutrition and its potential benefits and risks.

ARTICLE INFO

Received : 15 November 2021
Accepted : 11 April 2022
Published : 09 June 2022

Keywords:
Nanotechnology
Nanoparticle Performance
Rumen Fermentation
Livestock Nutrition

ABSTRACT

In recent years, nanotechnology has gained much attention within the scientific community in many countries. Nano mechanism is no longer a connotation or notion for the modern scientist only, but it has overturned into a recent enabling technique over the years, with the huge possibility of transformation. The field of cultivation and domestic animal so evolved in these sections can be conveyed to avian and animal offspring systems with the aim enhancement production efficiency and meeting human needs for quality poultry and animal products. As a result of the small size of nanoparticles, their passage is very fast through the walls of the gastrointestinal tract, creating many important effects in various body systems, which provides the opportunity for researchers to deal with nanomaterials by studying many veterinary fields, including production, reproduction, disease control, dealing with biological materials such as the study of DNA and cellular molecules.

1. Introduction

About 50 years ago, scientists rediscovered clay minerals for medical purposes, even though eating clay was used for hundreds of years by indigenous animals and cultures across the planet to improve healing. Studies have begun on the effects of various clay minerals on the health of free-ranging farm animals. Wild animals seek out clay deposits and use these minerals to detoxify the body from anti-nutritional compounds in the feed or to reduce digestive disorders. The method of eating clay, i.e. geophagy, has been described by several authors for both animals and humans. Adsorption capacity and its ability to release micronutrients are important properties of clay minerals. The role of clay minerals in binding harmful compounds and then their excretion from the body and antibacterial effects were also investigated.

Since 2006, the ban on the use of antibiotics as growth promoters in the member states of the EU (Regulation, EC No 1831, 2003) has had a significant impact on animal health and growth. Antibiotics provided good health, particularly in young animals resulting in a high output of animals in the later stages of fattening. At present, farmers have to deal with post-weaning diarrhea caused by gastrointestinal infections, particularly in weaned piglets. Accordingly, it is necessary to develop new alternatives to feed strategies and additives to ensure good health conditions and a high output of animals. The use of clay minerals is one possibility, and due to their adsorption capacity and the absence of primary toxicity, clay minerals could become suitable feed additives that ensure good health and the growth of animals.

Clay minerals with very fine, small particles and high adsorbent properties are most suitable for use in veterinary sciences. Kaolin and smectite are mostly used in animal nutrition as growth stimulants and supplements to treat digestive disorders, especially diarrhea. However, the clear mechanism of action of clay minerals in the body is not clear. Only a few clay minerals have special properties suitable for medicinal purposes. Modification of clay minerals can be a possibility to obtain materials with special properties required. However, the price of modified minerals can play a role in their application for veterinary purposes [1].

Nano means "dwarf" in Greek. Which is a size of about 10^{-9} meters, which is one-billionth of a meter. Everything around us is made of atoms, and in fact, the atom is the

Cite this article: Sheikhalipour, A; Taghizadeh, A.; Hosseinkhani A.; Palangi V.; Application of nanotechnology in animal nutrition. *NanoEra* 2*(1)*, 10–13

smallest building block of matter. From the Stone Age to the later ages and the present age, which is the age of silicones, human beings have always realized how and by what laws, billions of atoms are placed next to each other, and at the same time a shape and a model. They create something special and create macroscopic properties [2]. So, each atom and molecule, on its own, has certain physical properties that can be actualized and used to build new devices with extraordinary properties. The science that does this is nanotechnology. The simplest definition of nanotechnology is the technology that provides the power of structure and organization at the atomic and molecular level that has occupied mankind in the 21st century and will revolutionize human societies over the next few decades. Nanotechnology, as a new science, has been able to improve the performance of feed and increase the efficiency and production of animals by manipulating and modifying a material at the nanoscale [3,4]. Nanotechnology can improve food evaluation and act as a new tool for delivering nutrients to target tissues and a tool for explaining the metabolism and physiology of nutrients. The mineral particle size acts as food additives in the shape of nanoparticles from the intestinal wall and enters the body cells faster than normal materials with a larger size, thus improving bioavailability. There are also challenges to the emergence of nano-nutrients, including changes in the metabolism, toxicity, and environmental effects of nanoscale mutants compared to micronutrients, and so many consequences must be considered. Therefore, Nanometer size feeds can increase the bioavailability of feeds, production performance, and safety status of an animal [5].

2. The place of Nanotechnology in animal production

Nanotechnology can be described as the nano-sensitivity development of functional materials, devices, and systems by manipulating and processing new properties of structures in atomic-molecular size (one billionth of a meter). It is emphasized that nanometer-sized materials show different properties from normal-sized particles [6–8]. Due to their properties, it is reported that they are utilized in medicinal uses to increase the bioavailability of drugs and target therapeutic agents to certain organs, and reach deeper into tissues [9,10].

Although research in veterinary medicine and animal production is very limited today, nanotechnology has a wide use potential in Livestock production systems. Among these are the use of foods that cannot be offered for human consumption as animal feed, the improvement of feed quality, digestibility, and absorption, the production of feed additives, the production of special biosensors in animal breeding, the prevention of the spread of diseases, the determination of new materials and protection systems in pathogen identification [11]. For example, sensors and nanocapsule vaccines can be used for embryo mass production with micro and nanofluid systems, effective delivery of drugs to some parts of the body, monitoring of biologically very active medicine components and areas where farm animals are found. On the other hand, miniature/microrobots (nanobots) have been developed that allow a close-up examination of neural details in animals and can scan all capillaries [12].

Scott [11] points out the existence of nanotechnology applications in matters such as the use of feed additives, drug applications, the diagnosis and treatment of diseases with nanoparticles that enable the detection and elimination of the cause of the disease without the need for surgery, and the identity registration of an animal and its product (meat, milk, egg, etc.). The researcher also highlights the importance of nanotechnology in reproductive management with hormonal immunosensors, such as the development of immunosensors based on nanostructures that can detect progesterone concentration in cow's milk and facilitate the detection of ovulation in these animals [13].

3. Nanotechnology in animal nutrition

After the prohibition of the use of ionophore group antibiotics, which are used to eliminate health problems in animals and increased productivity, in recent years, the tendency to biotechnological methods has increased especially in the nutrition of farm animals in terms of health, performance, production quality, and natural feed additives (such as probiotics, prebiotics, enzymes, organic acids) have been started [14]. Nanotechnology, on the other hand, is not very different from biotechnology applications but is a new approach that has the potential to increase the efficiency of nutrients and their efficiency at the atomic and molecular levels. Nanotechnology can also be called 'nanobiotechnology' in the field of animal nutrition. Nanobiotechnology is the management of living organisms with nanotechnology by fusing biological and non-biological materials [15].

Studies on the use of nanotechnology in animal nutrition have mainly focused on evaluating the effect of fortifying nanoparticles of minerals. Nanometer-sized nanoparticles are used to increase the bioavailability of feeds due to the advantage of size effect and high surface reactivity, such as larger specific surface area, higher surface activity, higher catalytic efficiency, and stronger absorption ability, unlike normal-sized particles. Thus, it is possible to increase the developmental performance of the animal, the nutritional value and digestibility of the feed consumed, and thus the conversion rate of the feed. For the nutrients to be used effectively in the animal body, a large number of substances such as micelles, liposomes, nanoemulsions, biopolymeric nanoparticles, protein-carbohydrate nanoscale complexes, solid nano lipid particles are required. The nanoscale application system has been developed. These systems have better adaptability to environmental stresses and processing effects, high absorption and bioavailability, better solubility and dispersibility in aqueous-based systems, and controlled release kinetics [16]. Micronutrients and bioactive substances contribute to improving the overall health of animals. They can help achieve and maintain an optimal physiological state. These systems can help increase the quantity and quality of products and reduce the financial burden of producers, as well as more efficient use of nutrients [17].

On the other hand, since the bioavailability of minerals obtained from inorganic sources is quite low, these minerals are added to the feed mixes consumed by animals 20-30 times more than their normal requirement, which is a factor that causes excessive excretion of inorganic minerals with feces and thus increases environmental pollution. Alternatives such as organic mineral sources with much higher bioavailability than inorganic mineral sources are being studied. However, until now, there is little information on the suitability and efficacy of mineral nanoparticles in animal feeds [18].

4. The physiological role of nanoparticles

In this section, we will briefly describe how nanoparticles function in the body:

- It increases the surface area of the compounds, allowing the opportunity for biological reactions
- Increased persistence in the gastrointestinal tract
- Minimize the effects of intestinal secretory mechanism
- Due to their small particles, they penetrate deeply into the tissues through the tiny capillaries
- Crossing organs with epithelial tissue (e.g., liver)
- Enabling better absorption in cells brightens up
- Efficient transfer of active ingredients to the desired sites in body tissues [3].

5. Nanotechnology intervention in animal feed

Nanotechnology has four possible applications in animal nutrition. These four uses are:

- Prescribing medicine, nutrients, probiotics, etc.
- Diagnosis and treatment of diseases with nanoparticles allows to identify and eliminate the cause of this disease without the need for surgery.
- An identity register that allows you to track the history of animal products.
- Reproductive management with hormonal immunosensors.

Nanoparticles can also be used as additives to improve livestock production. Nanocapsules are also used as carriers of essential oils, flavors, antioxidants, vitamins and minerals, and phytochemicals for bioavailability [19].

6. Digestion and absorption

Nanoparticles can enter the gastrointestinal tract in a variety of ways, including water and food and using it as nanopharmaceuticals (swallowing pathway), as well as nanoparticles that enter through the respiratory tract. They also enter the gastrointestinal tract after purification in the respiratory tract (airway). The gastrointestinal tract is through the mucosa. Therefore, the smaller the particle size, the faster its release from the gastrointestinal mucosa occurs and ultimately causes rapid absorption through the gastrointestinal tract into the blood [20].

7. The role of nanoparticles in ruminal fermentation

The rumen is a complex ecosystem in which the consumed nutrients are digested anaerobically by microorganisms such as bacteria and fungi and the final product of food fermentation is VFAs, which are used by the host ruminants. The relation between the beneficial bacteria and the host animal results in an equivalent relevance that permits ruminants to digest fiber-affluent and minimal-protein materials. The fermentation process in the rumen is highly inefficient because it produces some final compounds like methane and ammonia. To improve the efficiency of microbial digestion, many food systems have been followed to change the path of microbial digestion in a way that serves the efficiency of the digestive process without affecting the health and productivity of the animal, to achieve this goal, the employed of minerals in the diet of animals has been directed towards, including nanoscale minerals because of their importance in improving the digestion process, As a result, its tiny particles along with the provision of a with its availability. Hassan et al, indicate that the addition of nano zinc at a dose of 20 mg/kg feed led to reduced methane production and improved level of antioxidants. This positive effect of nanoparticles by reducing the level of methane gas can be attributed to reducing the numbers of bacteria producing it or re-directing the hydrogen flow to bind to the receptors for producing propionate. The positive effect of these minerals also lies in their improvement of some digestive enzymes in the alimentary channel [3].

8. Potential risks associated with the use of nanotechnology in animal feed

What is needed is to assess the risk of nanotechnology in food and its impact on animals and humans. There is also a need for further research on the toxicological impact and potential hazards of nanoparticles for animal, environmental and human health. Potential hazards associated with nanoparticle nutrition include:(1) Increased bioavailability of nanoparticles compared to large shapes of the same material, (2) the prominent role of ROS-induced nanoparticles in gastrointestinal inflammatory diseases (3) Potential effects of nanoparticles on the stability and function of proteins and enzymes whereby metabolic processes may be disrupted or nutrient bioavailability may be altered, (4) Potential effects of storage, heating, and aging on the biomass complexes of nanoparticle molecules in feed [21].

9. Conclusion

In short, nanotechnology is a science that can be used in livestock diets to improve the bioavailability of nutrients, production performance, and the safety and health status of livestock. However, much research is needed in Relate to the usefulness and efficiency of nanotechnology and whether it is harmful or less harmful to the environment and humans.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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NanoEra 2(1), 14-18
NanoEra
ISSN: 2792-0666
https://dergipark.org.tr/nanoera

REVIEW ARTICLE

The role of nano-vaccines in animal science and health

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HIGHLIGHTS

- Nanotechnology is the practical science of fabrication and utilization of substances at a tiny scale in a variety of 1-one hundred nm.
- The use of nanotechnology in the preparation of nano-vaccines for animal health was discussed.
- Purification and modification of minerals to prepare nano-vaccines were investigated.

ARTICLE INFO

Received : 10 October 2021
Accepted : 18 April 2022
Published : 09 June 2022

Keywords:
Bio-available
DNA vaccines
Nanotechnology
Nanovaccines
Nanoparticle Performance
Livestock Nutrition

ABSTRACT

In recent years, researchers from various fields have tried to use them because of the increasing growth of nanotechnology. Technological applications in animal health have been a significant problem. However, it has overturned into a recent enabling technique over the years, with the vast possibility of transformation, and has potentially developed solutions. Nanotechnologies offer a wide range of prescription drugs for the diagnosis and treatment of diseases and reproduction. Nano-vaccines have emerged as a novel method of vaccination and are many more effective than traditional vaccines. Nano-vaccines trigger immune responses in the bloodstream and cells and prevent the spread of infection by destroying infectious agents by controlling the immune system. Also, advances have been reported in developing DNA-based vaccines for many diseases compared to conventional therapies. Objective: This review article aims to gather the materials and research that has been done to clarify the potential roles of nano-vaccines on animal health and their potential benefits and risks.

1. Introduction

Nanotechnology in animal science, is a powerful technology that can create a revolution and significant changes in the food and livestock supply system worldwide. Security of food and agricultural systems, enrichment and improvement of quality agricultural products, new cellular and molecular biology tool, intelligent transmission systems to animal diseases, and new materials to detect pathogens and protect the environment are examples of potential nanotechnology in the agricultural sciences. Nanotechnology addresses issues on a scale equal to those of viruses and other pathogens. Therefore, it has a high potential for identifying and eradicating pathogens; it also allows the use of drug delivery systems that can remain active for a long time. Designing drug-releasing systems have always been researchers' dream for drug-releasing systems, nutrients, and probiotics [1]. Today, one of the scientific challenges is using alternative food additives that do not produce antibiotic-resistant microbial species and increase resistance to stress and growth. Nanoparticles have various physiological and morphological properties, increased reflexive characteristics, bio-accessibility, persistence, regulated particle length, controlled delivery of medications, site-specific targeting, and managed pharmaceutical liberation. In addition, Nanoparticles can penetrate the cell, muscles, and limbs, creating a practical tool for medical performance [2]. In fact, vaccines are bioactive compounds that stimulate immune responses by delivering antigens to the immune system and equipping the body with more robust immune responses in the face of the primary pathogen. The use of nanotechnology in vaccine production science has found its way into areas ranging from ancient diagnostic methods to disease treatment, and it provided a new horizon to resolve the past challenges of developing effective vaccines. Nanotechnology has allowed different nanoparticles to develop in measure, composition,

Cite this article: Niazifar, M; Taghizadeh, A.; Palangi V.; The role of nano-vaccines in animal science and health. *NanoEra* 2(1), 14–18

form, and surface properties for pharmaceutical applications. Therefore, Nanometer size feeds can increase the bioavailability of feeds, production performance, and safety status of an animal [3].

2. The place of nanotechnology in disease recognition

The economies of many countries depend on the livestock industry, and the emergence of several viral diseases requires new disease prevention systems. Nanotechnologies must have the potential to enhance the supply of medicine and vaccines in veterinary medicine. By increasing the growth of the range of nanoparticles, new therapies will develop to treat viral or bacterial diseases and enhance the healing of deep wounds [4]. Nanotechnology has allowed different nanoparticles to originate in measure, composition, form, and surface properties for pharmaceutical applications [4].

Vaccines produced using recombinant DNA technology are a set of DNA-related techniques that make up the core gene replication. In this method of making a vaccine, after identifying the antigenic epitopes of the pathogen, the genes encoding these antigens are found. They are then introduced into cellular expression systems such as bacteria, viruses, mammalian cells, or even plants to produce large amounts of the active substance. These materials are used as recombinant vaccines after isolation and modification. Nano-sensors and nano-chips can detect diagnosis at the molecular level and on a single cell, enabling the diagnosis, information, and treatment of infections. Furthermore, nanoparticle delivery systems may have numerous distinguishing characteristics, containing excessive drug loading capacity, controlled clearance rate, and decreased drug toxicity within the body. Therefore, approaches based on nanoparticles as the release or assistive systems offer new possibilities to improve innate immune activation and induce a robust immune response to minor toxicity [5].

Nanoparticles designed with polyethylene glycol (PEG) can delay the release of the drug from the body. It makes the systematic circulation of the drug in the body longer than the free drug state and can eventually be helpful in further accumulating the medicine at the site of the disease. Using bio-degradable nanoparticles in vaccine formulations has improved antigen shelf life and immunogenicity, regular delivery to target tissues, and slow release. Therefore, nano-drugs are very useful in preventing and treating diseases. Vaccine delivery methods have developed, from intravascular and intramuscular injections to oral, inhaled, and dermal injections. However, some vaccines have commercials for oral administration [6].

3. Nanotechnology in safety system

In particular, nanotechnology in vaccinology has emerged hastily in recent years, leading to the creation of "nano-vaccinology." Recent decades have introduced a growing number of proteins and peptides as potential new medicine [7]. Although these Biopharmaceutical has revolutionized medicine by introducing new therapeutic opportunities, their poor bio-pharmaceutical properties and inadequate patterns of drug release rates are a difficult stage in their development as a drug that significantly affects their widespread use. Their appeal was improved drug stability, enhanced targeting capacity, and controlled drug release. Antigen-carrying nano-particles' can affect the immune response and substantially enhance the T-cell cytotoxic response against antigens fused to nanoparticles because of the specialized ability of some antigen-expressing cells, which can deeply absorb foreign particles such as micro-particles and bacteria [7]. Attribute this advantage are to the nanoscale particle size, associated lymphoid tissues, and effective antigen diagnosis and production. The interaction of immunogen with Nanoparticles, which is the central portion of a nano-vaccine for the connection of Nanoparticles, includes three distinct tracks: conjugation, sorption, and encapsulation (within the Nanoparticles) (Figure 1) [8]. This cellular nutrition process is carried out by detecting antigen material to analyze and express antigens foreign to other cells in the immune system. Nano-metric materials can enhance the effectiveness of vaccines because of their biomedical benefits. The nanoparticles also have many properties as helpers for vaccines; However, there are limitations such as nonspecific uptake through the intracranial turbine system and toxicity to the immune system with these compounds [9]. Nano-technology offers opportunities to increase substances for scientific usage, where traditional techniques can attain their limits.

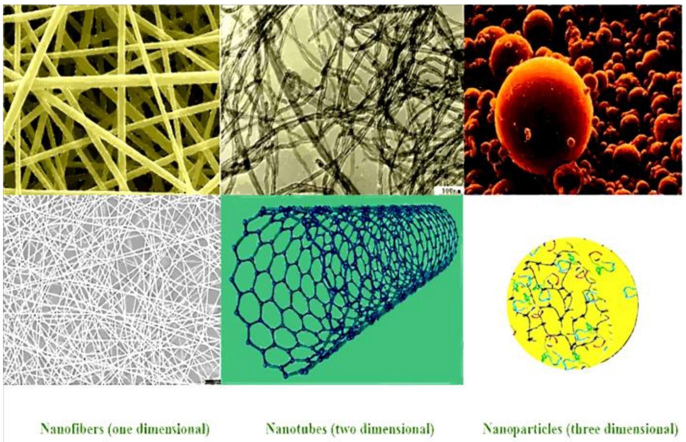

Figure 1. According to the proportions of the structural components, nanostructure substances are classified into three major types: nanofibers, nanotubes, and nanoparticles [9].

4. The emulsions of nano-vaccines

Can be used Nanoscale emulsions between 50 and 600 nm in size as an aid in vaccines. These nanoparticles may be present as oil in water or water-in-oil, in which an adequate surfactant stabilizes the nanoparticles. Emulsions disband polymers in the primary phase and form an emulsion with the aqueous phase. Dependent on the hydrophobicity of the vaccine, it may be the essential or aqueous phase of the emulsion. Polymer-encased emulsions act as nanocapsules by shaping a nucleus-envelope nanostructure [9]. The emulsions wil l be Trappe combining with antigen or pulling antigen into their nucleus to achieve the effective release of the vaccine. Emulsions present great potential in vaccine production science through nanotechnologies [10].

5. Nano-vaccines intervention in animal science

Nanoparticles have received much attention in recent years because they use a release system or immune system enhancers. Nano-vaccines have emerged as a novel method for vaccination. Nano-vaccines are more efficient than conventional vaccines and trigger blood and cell immune reactions. Vaccines inhibit infection by killing infectious agents controlling the immune system [11]. Vaccines advantage significantly from nanoparticle formulations, enhancing antigen perception and targeted APCs administration and enhancing immunogenicity and slow release of antigens. Because of their biodegradability, bioavailability, and minimal toxicity, most vaccine models containing these particles can be safe and effective alternatives to traditional vaccine formulas. It produced this new generation of vaccines with nanoparticles as vectors or adjuvants. Because of the similar size of nanoparticles and pathogens, they effectively stimulate the immune system. The activation of each cellular and humoral immune response followed the use of these vaccines [12]. The benefits of nano-vaccines include: Their best stability is in blood flow, Enhanced immune system stimulation, no boosters, and cold chain. Using nanoparticles' in vaccines offers two significant benefits. Firstly, nanoparticles act as adjutants, increasing the antigenicity of adsorbed or conjugated antigens and act as an antigen themselves. In this way, they can mimic the properties of pathogens such as viruses.

Secondly, the production of inflammatory cytokines intercedes many immunostimulatory responses initiated by NPs. Therefore, several nanoparticle structures are currently advanced for many applications. These structures can be both engineered or found naturally in the environment, and engineered Nanoparticles can specifically be designed to avoid interactions or target the immune system. This advantage is attributed to the nanoscale particle size (which facilitates uptake by phagocytic cells), associated lymphoid tissues, and efficient recognition and presentation of antigens. The interplay of immunogen with Nano-particles, which is the central piece of a nano-vaccine for Nano-particles incorporation, consists of three different ways: conjugation (covalent attachment), adsorption (on the surface of the NPS), and encapsulation (within the NPS) [13]. The other structures contain unique components that have gained much attention in the medical sciences, particularly in vaccines, such as liposomes, virus-like particles (VLPs), polymeric Nanoparticles, inorganic Nanoparticles, and the emulsions capability of Nanoparticles to fabricate synthetic vaccines to improve relating immune response and to act as vaccine delivery structures for a variety of substances (Figure 2).

It can induce an adaptive immune reaction and natural responses. Due to their high specific surface space and functionality, they are used as antigen carriers to improve antigen processing and offers. These qualities of Nano-particles have resulted in efficient cell targeting and the controlled release of antigens. Nanoparticles have abilities to both release antigens in a controlled manner and extend the half-life of most vaccines [13]. In addition, they can also act alone as immune potentiators. Added together are Resistant potentiators with adjuvants to influence T cells directly and their activation and improve antibody tigers. Nevertheless, in combination with immune potentiators, classical adjuvants have more complexity than improved immunogenicity [14].

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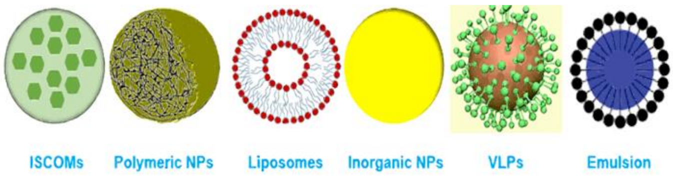

Figure 2. Structure of nanocarriers for vaccine antigen delivery [6].

6. Nano-vaccines intervention in animal health

The antigen-loaded nanoparticles can also target the lymph tumor, improving vaccine efficiency. There are many milestones in improving various types of veterinary nano vaccines, such as

1. Nano-emulsion vaccines, e.g., recombinant Bacillus anthracis spore-based and influenza virus vaccines, develop mucosa immunity after intranasal administering [16].
2. PLGA nanoparticles, e.g., Helicobacter pylori vaccine, Bovine parainfluenza type 3 vaccine, Tetanus toxoid, Bordetella pertussis vaccine, Rotavirus capsid vaccine, delivers IgG and IgA immune resistance after their oral management.
3. Chitosan nanoparticles (glucosamine biopolymer) can be distributed intranasal or pulmonary (e.g., TB vaccine) and S/C (e.g., recombinant Leishmania SOD vaccine) [16].

Other nano vaccines have additionally been advanced for veterinary use in opposition to FMD (gold nanoparticle-based vaccine), Newcastle disease (nano-capsule for oral administration), influenza virus (poly gamma glutamic acid vaccine for intranasal use, or Nano-patch TM for topical use), or herpes simplex (on calcium phosphate nanoparticles) and also African horse sickness virus (AHSV) vaccines with empty capsid and nucleus-like particles (CLPs) may be advanced the usage baculovirus-mediated co synthesis of African horse disease virus [17]. Such as (VLPs) of VP3 and VP7 (foremost middle proteins) and VP2 and VP5 particles (outer capsid proteins). The ensuing vaccine produces a weak immune response, requiring improvements in vaccine design [18].

7. Future Directions in nanovaccine

Vaccination includes a set of immunology, microbiology, molecular biology, investment and production costs and return on investment, and rules and regulations for vaccine use. The ultimate goal of any new vaccine is to produce a product needed for animal and human immunity against disease. Veterinary vaccines are involved in animals' health and high production, but they also play an influential role in human health [18]. Recently, vaccines have increased fertility, livestock production, and controlled livestock quantity in a particular group. Continuity of exchanges related to the rules and regulations for controlling animal and human diseases, scientific communication between researchers involved in animal and human diseases, and being prepared for the constant threat of emerging and re-emerging conditions are fundamental and essential [17].

A recent example of the emergence of the influenza virus of which poultry and wild birds are important vectors of the disease. Still, recent studies have shown that feral and domestic cats can also get the disease, and finally, the source may be the spread of the disease to humans. Pigs are susceptible to both human influenza virus and avian influenza virus. The simultaneous infection of pigs with the acute avian influenza virus and human influenza may cause the production of new strains of the virus that can be transmitted from human to human. Increasing the movement of animals from one region to another and the link between humans and wildlife, which is accelerated by global climate change, makes it essential to know about domestic animals and their products and nature, which play an indispensable role in spreading disease [17]. Human-transmitted has to take constant care. Significant progress has been made in producing effective vaccines and new types without side effects; however, we must add that many problems remain and are an incentive to use new technology in vaccine design. However, there are several new vaccines on the market. Still, they have less immunogenicity compared to living microorganisms, and identification of molecular and immunological properties of pathogens is required to increase the potency of killed and recombinant vaccines. Researchers need to do more research to find the pathogenic immunogenic antigens and increase their immunogenicity [19]. One of the best ways to increase the effectiveness of new and killed vaccines is to use new carrier systems, including plasmid DNA, nano- or microparticles, and living vectors. Essential points in immunology that are often overlooked in vaccine production are the critical role of innate immunity and the reactions of vaccine helpers. Intrinsic safety receptors for new compounds of active helpers and their associated ligands have been studied to enhance or enhance or regulate vaccine responses. The use of adjuvants in veterinary vaccines is not limited compared to human vaccines; in other words, in veterinary vaccines, there is more freedom in choosing helpers, and several helpers with different formulas are used in veterinary vaccines, but in human vaccines, only a few helpers are used [20].

On the other hand, in most cases, unfortunately, the details of the formula of veterinary assistants are not available to everyone due to their specificity. Information about helpers is not published, but there is hope that this case, in particular, will be reconsidered, and if possible, the formulation of helpers should be available to everyone. In general, existing barriers need to be removed for veterinary vaccines' success and commercialization [19].

8. Conclusion

The rapid improvement with the inside of the design and handling nano substances has endorsed the advancement of innumerable variations of the NPs. This service makes it possible to personify pharmaceutical operations. Nanotechnologies have led to unprecedented advances in all aspects of animal nutrition, including analysis, medicines, vaccination, animal composition and production, food, and health. Other applications of nanotechnology in animal science and animal health can be used in tissue engineering and the production of new tools for cellular and molecular proliferation, preservation and identification of animal reproductive processes, animal nutrition, the safety of animal food products, conversion of animal waste to feasible material consumption, and diagnosis of pathogens noted. The development of nanotechnology will revolutionize animal science and animal health and potentially enhance controlled practices, from nanocapsule vaccines to sex selection in reproduction. However, the economy and public opinion still need to focus on pharmaceutical nanotechnology and nanotechnology-based therapeutic advances to make them more prevalent in the future.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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NanoEra 2(1), 19-22

NanoEra

ISSN: 2792-0666

https://dergipark.org.tr/nanoera

REVIEW ARTICLE

Application of nanomaterials in animal sciences

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HIGHLIGHTS

> The purpose of this article is to review the use of nanotechnology in the livestock industry and the effect of nanomaterials on ruminant nutrition.

ARTICLE INFO

Received : 01 November 2021
Accepted : 28 December 2021
Published : 09 June 2022

Keywords:
Nanomaterials
Ruminants
Growth Performance
Reproduction and Health

ABSTRACT

Nanoscience is one of the newest technologies in the world that is widely used in all fields of science and technology such as agriculture, medicine, pharmacy, environment, etc. One of the reasons for the pervasiveness of this technology in all sciences is related to its cross-science nature. This technology has received more attention in recent years due to its low cost, better and faster performance, high stability, and high repeatability. With this technology, farmers can have animals of superior breed and high production and experience the best performance by minimizing various diseases and have a high efficiency of milk and meat production at a lower cost.

1. Introduction

Nanotechnology is the science of controlling matter in nanometers. Nanomaterials have unique properties due to their small size (1-100 nm) and have many applications in industries and sciences various, including animal sciences. Applications of nanomaterials in animal sciences include health, drug delivery, higher production, and better quality milk and meat. Mineral nanomaterials are also used in the feed of livestock. Inorganic nanomaterials, due to the small size [1], stability at high pressure and temperature [2], small size and less space occupation, and larger impact area [3] (current perspective and future), have a high absorption capacity in the gastrointestinal tract [4]. The properties of mineral nanomaterials are known by their size, shape, and crystal structure [5]. Some nanomaterials with a surface function can bind to toxins and pathogens and cause their removal [6]. Nanomaterials (nano silver, nano zinc, and nano selenium) can also be effective in health and improving product quality [5].

2. Types of nanoparticles

Nanoparticles can be classified into metals, polymers, natural compounds, and nanostructured materials. Due to the fact that each group has different engineering processes, they perform different biological functions through various mechanisms. Metal nanoparticles are used in imaging and antimicrobial therapy. Metal nanoparticles in the treatment of antimicrobial kill gram-positive and negative bacteria and in this regard have been considered in medicine. However, the accumulation of metal nanoparticles in the body should be avoided because it may have harmful effects [7]. With the spread of magnetic nanoparticles in different parts of the body, MRI imaging is possible. In Feed additives in the form of nanoparticles in animals due to their availability, better performance and absorption in the intestine. Nanopolymers are synthesized polymers of nanometer size that have the ability to bind to other materials and have a positive effect on their biocompatibility and degradability. These properties of nanopolymers are considered in medicine because they have few harmful effects on patients. Nanopolymers destabilize bacterial cell walls to kill bacteria, greatly damaged bacterial function. Nanostructured materials are derived from various nanoparticle-based compounds such as lipids and proteins. These substances act as carriers of nutrients or drugs in the body. Damaged sperm can also be identified and removed by antibodies attached to nanoparticles. Natural nanoparticle-based compounds are also naturally obtained with little modification, like proteins. Natural nanoparticles and nanostructures can act as carriers

Cite this article: Delir, S.; Taghizadeh, A.; Paya, H.; Palangi, V.; Application of nanomaterials in animal sciences. *NanoEra* 2(1), 19–22

of functional groups such as nutrients. Natural nanoparticles can be safer. Dietary supplements in the form of nanoparticles can increase the bioavailability of nutrients and also prevent the breakdown of nutrients in the stomach by encapsulation [6].

3. Nutrient delivery

Manipulation of nanoparticles such as casein micelles naturally present in milk and the accumulation of some casein forms around calcium and proteins, etc., can lead to the synthesis of hydrophobic nutrients [8]. Researchers have found that vitamin D in these nanoparticles increases their bioavailability due to proteolytic breakdown in the stomach and the release of vitamins [9]. This increase in bioavailability can lead to high growth in young animals, which can become overweight and highly productive animals in the future. Due to the fact that the different parts of the gastrointestinal tract of ruminants have unique properties, nanoparticles must be able to act according to the conditions of different parts of the gastrointestinal tract to increase their impact and absorption. Nanoparticles pass hydrophobic and hydrophilic compounds through the stomach in a protected manner to reach the intestines and must function as if they originate from the feed. Digestible nanoparticles are digested in the gut and otherwise excreted naturally from the body [6].

We briefly mention the mechanism of action of nanoparticles in animals:

1. Increased surface for binding to biological agents
2. Increased long-term storage of compounds in the gastrointestinal tract
3. Orientation of active components to the desired targets in the body
4. Significant reduction in gut cleanse
5. Allowing cells to absorb effectively
6. I Perforation of the cross-section of the epithelial coating in tissues, e.g., liver
7. Penetrating deep-rooted into the tissues through thin capillaries

4. The effect of nanoparticles on ruminal fermentation and growth performance in ruminants

Nanoparticles such as nano-minerals (selenium nanoparticles and zinc nanoparticles) positively affect ruminal fermentation and nutrient digestibility by increasing the surface to volume ratio, nanoparticle size, and catalytic and rapid efficacy. It also improves the bioavailability of mineral nanomaterials in the gastrointestinal tract. Mineral nanomaterials promote better growth of the animal by positive changes in the intestine and improvement of ruminal fermentation (increased fiber digestion and redox reaction). The researchers [10] stated that zinc nanoparticles (200-100 mg/kg) increased volatile fatty acids, microbial crude protein, and decomposition of organic matter in 6 to 12 hours after incubation in vitro ruminal fermentation conditions. Similarly, zinc nanoparticles in experiments [5,11] and selenium nanoparticles [12] increased the digestibility of dry matter, organic matter, crude fiber-free extract, and finally increased the weight of lambs.

The beneficial effects of nano-silver on production have been reported by Albanese [3] and Elkloub [13]. These positive effects can be attributed to the strong antibacterial, antifungal, anti-protozoan, and even antiviral activity of silver nanoparticles. It is also possible that under conditions of commercial farm stress, the concentration of pathogenic bacteria will increase, and as a result, the effect of silver will be greater. These positive effects can be attributed to the strong antibacterial, antifungal, anti-protozoan, and even antiviral activity of silver nanoparticles. It is also possible that under conditions of commercial farm stress, the concentration of pathogenic bacteria will increase, and as a result, the effect of silver will be greater. Arshad et al. [14] reported that selenium improves GSH-Px activity in microorganisms. Selenium is used to synthesize microbial proteins and cell wall components. Increased microbial protein production improves the production of volatile fatty acids, microbial population and decreases ammonia nitrogen.

Shi et al. [15] and Xun et al. [4] have reported that Se NPs improve the function of bacterial degrading proteins and the production of protein degrading enzymes.

Rumen pH balance and microbial population are critical for balanced rumen fermentation. Acidic pH impairs fiber digestion because it prevents bacteria from attaching to the plant cell wall. Studies by Shi et al. [15] found that the use of nano-selenium increased ruminal fermentation by improving and balancing microbial fermentation and ruminal pH in sheep.

5. Application of nanomaterials in the health of ruminants

Mineral nano-materials reduce free radicals and increase antioxidant activity by increasing the surface area and improving the health status of animals. Experiment [12] in male goats receiving selenium nanoparticles showed a significant increase in serum selenium and SOD superoxide, catalase, and glutathione peroxidase. These enzymes have an antioxidant role and eliminate oxidative stress factors such as malondialdehyde (MDA) [12]. Nanomaterials can also play a protective role against physiological disorders [16]. Selenium nanoparticles have been shown to protect cardiac cells against abnormalities and have positive effects [16]. Zinc oxide nanoparticles can also have antibacterial activity and effectively treat bacterial diseases.

6. Application of nanomaterials in animal reproduction and breeding

Finding estrus on the farm is difficult, costly, and time-consuming for industrial livestock. During estrus, estradiol changes in the blood can be used to identify estrus animals to be inseminated at the appropriate time. Today, specialists use nanotubes implanted under the skin to detect estradiol levels in the blood and track estrus animals [15]. Other nanomaterials include biological chips, which are used to physically classifysperm and ovum, allowing dysfunctional genomes and genetic diseases to be identified and removed as quickly as possible. Therefore, farmers can identify animals of a superior breed that have high production [17].

Recent research suggests that some nanoparticles increase fertility and protect sperm. Artificial insemination in livestock production is considered due to the lack of risks due to natural insemination for animals and breeders due to the selection of superior livestock traits. Nanotechnology can enhance this method (non-invasive bioimaging of gametes, nanofiltration, and preservatives in sperm freezing). In this regard, mineral nanomaterials are preferred to organic fluorescent molecules due to their high biocompatibility, high stability, and high signaling intensity [18,19]. Quantum dots are another method that detects and images molecular and cellular processes during fertilization and at a greater depth in the tissue, which is a function of the size, wavelengths, and probability of ovum and sperm mating [18,20]. Appropriate concentrations of quantum dots should be used to reduce cytotoxicity.

Defective sperm can be isolated in the reproductive cycle by seminiferous semen filtration. Several methods have been identified for nanofiltration, including antibody and lectin techniques. With this method, more female animals can be inseminated using diluted semen, which improves fertility [21].

Shahin et al. [22] stated that gene transfer was made possible by using silica nanoparticles. In this method, nanoparticles have a strong relationship with sperm and have no adverse effect on sperm, and ultimately improve its fertility [23]. Despite the many applications that nanoparticles have in reproduction, they can also be harmful and reduce sperm quality. Toxic nanoparticles include zinc oxide and titanium oxide nanoparticles, which increase sperm death by weakening membranes and fragmenting DNA [6]. To this end, [24] conducted an experiment using zinc oxide nanoparticles on human sperm and found that this substance reduced sperm survival by 50%. Therefore, it is necessary to be careful when using nanoparticles when using them [6].

7. Application of nanomaterials in improving the quality of animal meat

There are various methods to improve the quality of livestock meat using nanotechnology, such as encapsulation, spray drying, melt extrusion, coagulation, grease coating, and spray cooling. These systems cause changes in taste, delivery of several active ingredients, and long shelf life of meat. Today, researchers produce meat in the laboratory that has the potential to be even richer in nutrients than ordinary meat obtained by slaughtering animals [25].

8. Application of nanotechnology in milk production and safety

Milk can be contaminated by endogenous and exogenous agents and can cause disease in humans and newborn animals when consumed. Among the pathogens in milk, we can mention Staphylococcus, Streptococcus, Bacillus species, and Escherichia coli [26]. These pathogens contaminate milk and eventually cause disease by producing toxins. Therefore, it is necessary to identify these pathogens in milk before consumption, and special attention should be paid to it. Researchers [27] used hydrogenated castor oil solid lipid nanoparticles to identify Staphylococcus aureus pathogens. According to the experiment, the researchers said that by balancing the dose of nanocarriers and their half-life, milk loss could be minimized [6]. Other nanomaterials used to identify pathogens in milk are nanocomposites (gold nanoparticles and magnetic nanoparticles) containing antibodies. The unique feature of these nanocomposites is related to antibodies that can absorb pathogens.

9. Conclusion

Nanotechnology is a creative science that has a lot of potential and can affect society, the environment, animals, and many other issues in the world. In the near future, this technology in the discussion of diagnosis and treatment of diseases will make significant progress compared to the past and reduce costs and waste time. Also, the use of nanomaterials in animal nutrition by affecting ruminal fermentation, digestibility, and antioxidant activity improves milk and meat production compounds. Consequently, human health is guaranteed by consuming these products.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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