Egyptian Journal of Animal Health

P-ISSN: 2735-4938 On Line-ISSN: 2735-4946
Journal homepage: https://ejah.journals.ekb.eg/

Urgency and Challenges of Digital Transformation in Animal Healthcare Based on Industry 4.0

Ashraf E. Sayour [*], Hossam E. M. Sayour[*], Momtaz A. Shahein[**], Samah Eid[***], Ahmed M. R. Fath El-Bab[****], and Hani F. Ragai[*****]

*Molecular Biomimetics Research Group, Animal Health Research Institute, Dokki, Giza 12618, Agricultural Research Center, Egypt
**Department of Virology, Animal Health Research Institute, Dokki, Giza 12618, Agricultural Research Center, Egypt
***Reference Laboratory for Veterinary Quality Control on Poultry Production, Animal Health Research Institute, Dokki, Giza 12618, Agriculture Research Center, Egypt
****Mechatronics and Robotics Department, Faculty of Engineering, Egypt-Japan University of Science and Technology, Alexandria 21934, Egypt
*****Department of Electronics Engineering and Electrical Communications, Faculty of Engineering, Ain Shams University, Cairo 11331, Egypt

Received in 1/5/2023
Received in revised from 7/5/2023
Accepted in 9/5/2023

Keywords:

digitalization
veterinary healthcare
e-clinic
biosensor
industry 4.0
IoT
AI

ABSTRACT

Veterinary healthcare encompasses various activities such as prediction, prevention, monitoring, diagnosis, and treatment of livestock. This article reviews the advantages and challenges of digitalizing animal health and highlights its urgency in terms of national security. The advent of novel technologies and their widespread use in animal healthcare has facilitated the tracking of animal and product movements in the supply chain, monitoring their health in real-time, and utilizing data analytics and machine learning to identify patterns and trends in animal health. Technology has made possible the detection of disease outbreaks before they spread, the stoppage of zoonotic disease spread, and the improvement of the general health and welfare of animals. This requires financial support, cooperation among team members, and commitment to data security and privacy. We must take the digitalization of animal health seriously and invest in the infrastructure and technology required to manage it because it is a pillar of national security.

*Corresponding author: Hossam E. M. Sayour , Molecular Biomimetics Research Group, Animal Health Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.
E-mail address: Hossam.sayour@gmail.com
DOI: 10.21608/EJAH.2023.298408

INTRODUCTION

Veterinary healthcare involves prediction, prevention, monitoring, diagnosis, and treatment of livestock. The emergence of new technologies and the exponential increase in their application in animal healthcare has enabled the monitoring of animal and product movements in the supply chain, real-time tracking of their health, and utilization of data analytics and machine learning to detect patterns and trends in animal health. These advancements have led to notable transformations in farms of all sizes, resulting in decreased losses, enhanced animal welfare and health, precise animal care, and a rise in the output of meat, milk, and eggs. New technologies such as milking robots, wearable sensors, and heat detectors have been implemented to maximize the outcomes of cattle breeding.

Still, digitalization poses challenges such as the need for standardization and interoperability of data, as well as concerns regarding data privacy and security. This article examines the advantages and difficulties of digitalizing animal health and highlights its urgency in terms of national security.

Veterinary Telemedicine

The application of technology to deliver animal healthcare remotely is known as veterinary telemedicine. Through the use of video conferencing, phone consultations, and other digital communication tools, it enables veterinarians to diagnose, treat, and monitor animals while working remotely. Since it enables pet owners to receive veterinary care without having to leave their homes, telemedicine in veterinary medicine has grown in popularity in recent years, particularly during the COVID-19 pandemic. Additionally, it gives veterinarians an easy way to keep track of and follow up on their patients without having to make personal visits.

There are many services that can be provided by veterinary telemedicine, including consultations and follow-up care without requiring an in-person visit. Veterinarians can also diagnose an animal by remotely interpreting diagnostic tests like blood work or X-rays. The use of digital technologies like electronic health records and telemedicine enables veterinarians to handle livestock information and interact with owners in a more effective manner, which ultimately decreases the amount of time and resources required to deliver care.

There are several conditions that can be diagnosed remotely through the use of telemedicine, e.g., skin and eye conditions, behavioral issues, respiratory infections, and gastrointestinal problems. Diagnosis can be fulfilled by asking the animal owners to describe the complaint and send photos or videos showing the lesions or symptoms. On the other hand, telemedicine has some limitations including difficulty to conduct a full physical examination and lab testing remotely. A remote location might not have access to specialized equipment or a sterile environment necessary for some procedures. In veterinary medicine, establishing a relationship with an animal and its owner is crucial. Failure to build this connection through telemedicine may have an effect on the standard of care given.

The Potential of Digital Transformation in Animal Healthcare

The use of technology to enhance animal welfare, stop the spread of disease, and guarantee the security of our food supply is known as digitalization in the field of animal healthcare. Animal health digitalization in is primarily intended to improve the efficiency of animal health management and monitoring. This entails using sensors, drones, and other technologies to continuously monitor animal health as well as data analytics and machine learning to spot patterns and trends. Utilizing digital transformation in the field of animal healthcare has many potential benefits.

A. Early Detection and Prevention of Disease Outbreaks

The ability to quickly and accurately identify disease outbreaks is one of the main advantages of digitalization in animal health. Real-time animal health monitoring is now possible with the aid of sensors, drones, and other

technology, allowing for the early detection of disease symptoms. This can be crucial in the case of zoonotic diseases, which can spread from animals to people and have the potential to spark pandemics around the world.

Diagnosis of diseases through physical samples has become more efficient, portable, and simplified with the advent of microfluidic devices, also known as small chips, that can examine very small amounts of fluid without requiring laboratory processing. Digital monitoring devices can detect exposure to infectious diseases and track outbreaks in real-time, allowing for preventative measures like vaccination or quarantine protocols.

In 2016, a flock of turkeys in Lincolnshire, UK, tested positive for the H5N8 avian influenza virus. The government established a 10-kilometer surveillance zone around the affected farm soon after the outbreak was discovered, and all of the nearby poultry were tested for the virus. These steps prevented the outbreak from spreading further, and no new cases of the illness were noted in the UK.

B. Prediction of Animal Health Problems Before They Take Place

Advanced artificial intelligence and machine learning are utilized in predictive technologies to develop personalized and targeted care plans that can predict potential issues and implement suitable preventative measures. Using predictive analytics to anticipate animal health issues in advance is a beneficial approach to avoid or reduce the negative effects of potential health problems on animals. The techniques and strategies employed to predict animal health problems vary depending on the animal species and the particular health issue.

One approach is to consistently watch the behavior and physical condition of the animal. This could involve tracking their eating habits, level of movement, and any changes in their appearance or actions. By paying attention to these factors, it may be possible to detect early signs of illness or injury and deal with them before they become more serious. An alternative approach involves utilizing technology, such as wearable gadgets and sensors, to observe the animal's behavior and vital signs. These devices can track heart rate, temperature, and movement patterns, which can offer significant information to identify any alterations that may suggest a health issue.

Digital transformation technologies can be used to predict a variety of health problems in animals. For instance, an animal's gait and movement patterns can be tracked to detect any signs of lameness or joint problems. Ultrasonography and hormone monitoring can predict and manage reproductive issues. Changes in breathing patterns can indicate respiratory problems. Thermal imaging involves the use of cameras and heat sensors to observe temperature fluctuations in groups of animals, including specific body parts like hooves and udders. AI-based image recognition of parasites in pet stools can speed up the deworming process, minimizing the risk of worms spreading within the household. Smart ear tags can monitor four important aspects in cows, including their eating habits, movement, heat detection, and fertility. This data is transmitted every 20 minutes, giving an exact and current overview of the health of each animal. The analysis of large amounts of data can turn diagnostic records into a preventative tool, enabling early detection of illnesses.

C. Tracking Animal Movement and Product Traceability

The ability to track the movement of animals and their products throughout the supply chain is another benefit of digitization. It is possible to track the source of meat, dairy, and other animal products and make sure they are safe for consumption by using blockchain technology and other digital tools. By doing this, you can limit the spread of foodborne illnesses and give consumers confidence that the food they eat is safe.

Another advantage of digitization is the capability to track the movement of animals and their products throughout the supply chain. Using blockchain technology and other digital tools, it is possible to trace the origin of meat, dairy, and other animal products and ensure

their safety for consumption. This will help to stop the spread of foodborne illnesses and reassure consumers that the food they are eating is secure.

There are several techniques for digital tracking of animal movement and product traceability. GPS tracking technology can be utilized to track the movements and whereabouts of animals by attaching tracking devices to them, providing real-time monitoring. Electronic identification tags have the capability to recognize and monitor individual animals from the time they are born until they are processed.

D. Progress in Individual Animal Healthcare Like Never Before

The use of digital technology has reduced the need for constant monitoring and improved communication between humans and animals. Thanks to digitalization, farmers can accurately pinpoint the first sick animal in a large group by observing signs like coughing, elevated body temperature, and behavioral changes by sound, temperature, and video monitoring systems respectively. Smart collars enable pet owners to recognize early indications of sickness such as lack of energy and decreased appetite.

In order to improve the health of both individual animals and the entire population, it is possible to identify patterns and trends in animal health using data analytics and machine learning. The generation of cumulative knowledge is becoming more common in the creation of veterinary intelligence systems, which can anticipate changes in an animal's health status before they happen. This enables the implementation of preventive measures and personalized health plans. There are already tools available that can gather and compare animal health data, and notify a veterinarian of a potential problem based on the animal's behavior, biological indicators, or diagnostic results.

The use of antibiotics and other medications, which may have detrimental effects on the environment and public health, may be reduced as a result of the digital revolution. In 2018, scientists at the University of California, Davis, created a machine learning algorithm that had a 90% accuracy rate in predicting when cattle in feedlots would start to develop bovine respiratory disease (BRD). Early disease detection makes it possible to treat affected animals with focused care, which lowers the need for antibiotics and enhances animal welfare.

E. One Health Benefits of Digital Transformation

The One Health approach is strengthened by the improved capacity to predict a shift in health condition to take action before a disease or epidemic occurs, thereby safeguarding the health of animals, humans, and the environment. The use of antibiotics can be reduced to minimize the risk of drug resistance and environmental exposure. Responsible use programs can be implemented to treat sick animals while preserving the effectiveness of antimicrobials. Vaccination and control programs can also be put in place to lower the risk of disease spreading to other animals and humans. Early detection of zoonotic diseases can prevent them from spreading to nearby people. This can lead to fewer losses in food production, resulting in improved food and nutrition security.

Digital technology can make it easier for parties involved in animal, human, and plant health as well as environmental specialists to communicate with each other. One way this can be achieved is through teleconferencing platforms that allow for mutual cooperation and remote consultation.

The E-Veterinary Clinic as a Digital Healthcare Platform

The term "electronic veterinary clinic" has become popular in some veterinary faculties in Egypt and other Arab countries. However, it is simply a digital version of some services offered by traditional clinics, accessed through mobile networks and the internet. Figure 1. This dilutes the true meaning of the term, which should refer to a new technology used by veterinarians, farmers, and pet owners to

remotely monitor animal health and care, particularly in remote locations 24/7. This technology provides a better veterinary medical service at a lower cost within a traditional clinic or an independent entity based on artificial intelligence, machine learning, and fourth-generation technology of communications and the Internet of Things

The growth of the livestock sector has led to the development of cost-effective and quick digital tools (e-clinics) that are specific to each species. These tools can assist veterinarians in managing the constant influx of animals coming into their clinics. A variety of services, such as consultations, diagnoses, treatments, and medication prescriptions, are frequently provided by e-veterinary clinics. Point-of-care testing offers quick outcomes without requiring an outside laboratory, providing instant solutions to worried pet owners. For animals with chronic conditions, some online veterinary clinics may also provide follow-up care and monitoring.

Remote pet owners can access veterinary services from an online clinic. It enables communication between pet owners and veterinarians over the phone, video, or the internet. For pet owners who might not have access to conventional veterinary clinics or who prefer to seek veterinary guidance from the comfort of their own homes, this platform offers a practical and accessible option.

Increased accessibility to veterinary healthcare is one of the advantages of e-veterinary clinics. These virtual clinics provide a more practical choice for owners who might have hectic schedules or have trouble getting their animals to a conventional veterinary clinic. E-veterinary clinics are specially useful in urgent situations where a veterinarian's advice is required right away.

E-veterinary clinics, however, do have some drawbacks. A physical examination or diagnostic tests that cannot be performed remotely may be necessary for some conditions. They might not be able to offer urgent care or immediate surgical intervention.

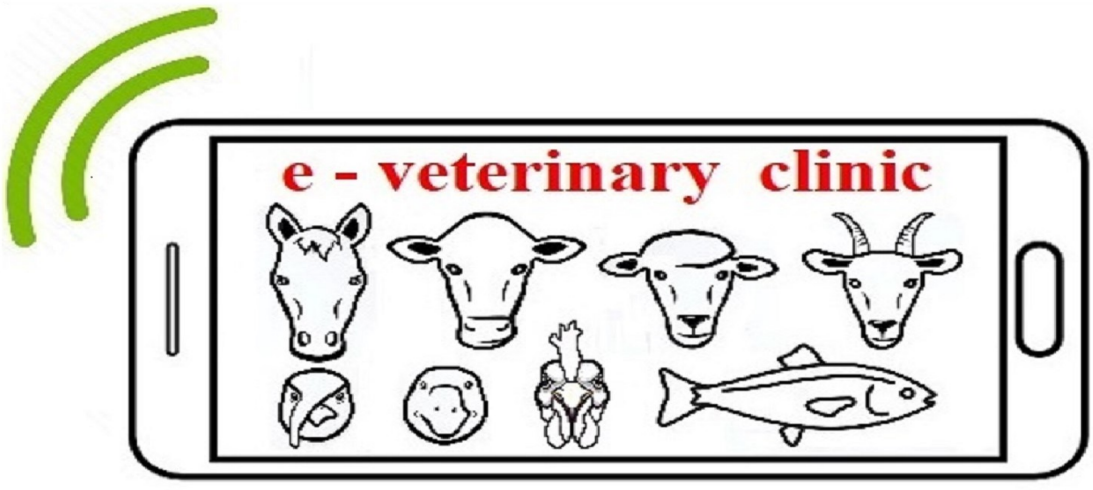

Figure 1: Diagram of an electronic veterinary clinic on a smartphone

Smart Materials Based on Molecular Qrchitectonics

Molecular architectonics involves designing molecular building blocks with functional cores and auxiliaries and controlling their self-assembly to create molecular architectures with specific properties and applications. This field is influenced by concepts such as molecular recognition and host-guest chemistry, which use noncovalent interactions to drive molecular assembly. Molecular tailoring based on host-guest dimensions is a key aspect of designing and developing advanced materials. Mechanistic insights from biomolecular assemblies guide the design of biomimetics and biomaterials, and the combination of synthetic and biological components generates hybrid biomaterials. Molecular architectonics is also used to develop biosensing platforms that can quickly and accurately detect analytes. Scientists have been working to create artificial antibodies that mimic the recognition ability of natural antibodies, but with greater stability and durability. These synthetic molecular architectonics can replace natural recognition elements and are being developed for use in low-cost, easy-to-use diagnostic tests for diseases.

Various global organizations, including WHO, OIE, FAO, and EPA, have urged the creation of affordable, user-friendly, and efficient diagnostic tests for identifying pathogens in the early stages. The expense of reagents, advanced laboratory equipment, and skilled personnel has made disease detection and monitoring a significant challenge. Additionally, it is difficult to locate laboratories in remote areas affected by epidemics. Advances in molecular biology, nanotechnology, and BioMEMS are making it possible to remotely diagnose diseases using Lab-on-a-chip technology.

Development of Biosensors as the Key Tools for E-veterinary Clinics

Biosensors are devices that can detect and measure biological signals, such as changes in temperature, pH, or the presence of specific molecules, and convert them into electrical signals that can be analyzed by a computer or other device. Biosensors are used in a variety of applications, such as diagnosing diseases in humans and animals, monitoring environmental conditions, and detecting chemical pollutants.

Biosensors can help to monitor the health of animals in real-time and provide early detection of health problems, which can be particularly useful for livestock and other animals that are difficult to monitor manually. Biosensors can also track the movement and behavior of animals, which can provide valuable insights into their daily activities and help to ensure their safety.
Figure 2.

Some of the key challenges in building biosensors include developing sensors that are accurate, reliable, and easy to use, as well as ensuring that they are compatible with the specific needs of different animal species and environments. Additionally, there are ethical considerations that need to be taken into account, such as ensuring that biosensors are not harmful to animals and that the data collected is used responsibly.

Despite these challenges, there are many promising developments in the field of biosensors for animal health digitalization. Researchers are exploring the use of wearable biosensors that can be attached to animals to monitor their vital signs and behavior, as well as the use of implantable biosensors that can provide even more detailed information about an animal's health. Advances in artificial intelligence and machine learning are making it easier to analyze the vast amounts of data generated by biosensors and use it to improve animal health outcomes. The use of advanced data infrastructure and analytics is enabling the gathering of knowledge from various regions and animals worldwide. This allows veterinarians to access insights from others' experiences to improve their understanding of treatment options for rare illnesses. Researchers can utilize machine learning to analyze numerous animal profiles and diagnostic results to identify subtle health changes and develop new prevention protocols. Retailers can rely on digital traceability systems to track the

production process of animals and their products, which helps them inform consumers about the safety and sustainability of their products.

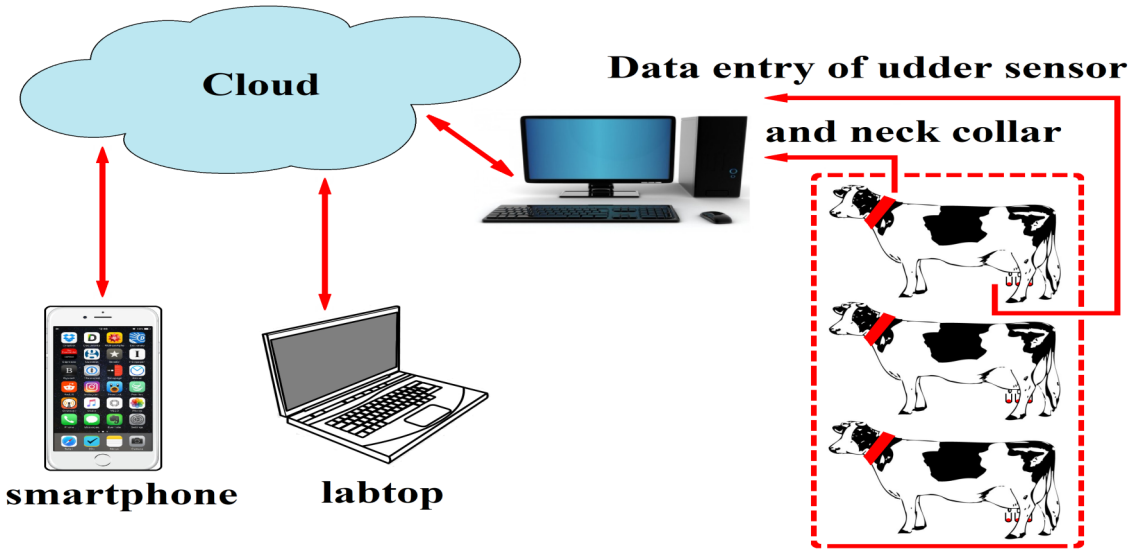

Figure 2: Diagram of a model smart farm

Veterinary Healthcare Informatics to boost telemedicine

Veterinary healthcare informatics is a field that combines veterinary medicine and information technology to improve the efficiency of veterinary healthcare. Information about animal health is managed and analyzed using digital scientific records, data analysis, and other applied sciences. The purpose of veterinary healthcare informatics is to give vets the resources they need to make wiser decisions regarding animal health and raise the standard of veterinary care as a whole. Veterinarians can easily access and manage patient data, such as medical history, results of diagnostic tests, and treatment plans, by using electronic medical records.

Veterinary healthcare informatics uses telemedicine, another technology that enables veterinarians to diagnose and treat animals remotely, in addition to electronic medical records, to provide remote consultations and other services. Additionally, it involves the use of data analysis tools to spot patterns and trends in disease and animal health, which can aid veterinarians in creating more efficient treatment regimens.

Digitalization of Animal Health as a High Priority for National Security

National security is significantly impacted by the digitalization of animal health. The potential for animal disease outbreaks to deplete food supplies and harm the economy is one of the main worries. For instance, a foot-and-mouth disease outbreak in the UK in 2001 led to the slaughter of millions of animals and incurred estimated costs to the UK economy of £8 billion. There is a growing understanding that animal health is a crucial aspect of national security as similar outbreaks in other nations have had similar effects.

In addition to the financial costs associated with animal disease outbreaks, zoonotic diseases have the potential to spread from animals to people and result in pandemics around the world. Understanding and managing animal health is crucial for both public health and national security, as demonstrated by the COVID -19 pandemic, which is thought to have started in bats.

Digitalization has a significant impact on both preventing and combating these threats.

Real-time animal health monitoring allows for the early detection and containment of outbreaks before they have a chance to spread. Food safety can be ensured and the spread of foodborne illnesses can be stopped by tracking the movement of animals and their products throughout the supply chain. In order to improve the health of both individual animals and entire populations, it is possible to identify patterns and trends in animal health using data analytics and machine learning.

However, these advantages can only be attained if data security and privacy are safeguarded. As was already mentioned, there is a chance that private data on the movement and health of animals could be stolen or used maliciously. This might have detrimental effects on both national security and animal welfare. In order to protect data privacy and security, it is crucial that the proper safeguards be put in place. These safeguards should include the creation of shared standards for data collection and analysis as well as the use of encryption and other security measures to protect sensitive data.

Challenges and Recommendations for Animal Health Digitalization

Even with the abovementioned advantages, there are some drawbacks to the digitalization of animal health. The requirement for data security and privacy is one of the major challenges. There is a chance that the sensitive data being gathered and analyzed will be misused or stolen. Due to the possibility that malicious actors could use sensitive information about animal health and movement to contaminate food supplies or spread disease, this could have serious repercussions for both animal welfare and national security.

The requirement for data standardization and interoperability presents another difficulty. It can be challenging to integrate and analyze the data from so many different sensors and data sources in a meaningful way. This may result in inefficiencies and lost chances to enhance animal health and stop disease outbreaks.

Increased cooperation between government organizations, business leaders, and academic researchers is required to address these issues. By collaborating, it is possible to create common standards for data collection and analysis and to guarantee the security and privacy of the collected data. This will necessitate a sizable investment in technology and infrastructure, as well as in the education and training of those who will be using these new tools.

CONCLUSION

The digitalization of animal health may have an impact on how disease outbreaks are managed and how sane our food supply is. By utilizing new technologies and data analytics, it is possible to detect disease outbreaks before they spread, stop the spread of zoonotic diseases, and improve the general health and welfare of animals. But doing so will demand a sizeable outlay of cash, lots of cooperation among team members, and a commitment to data security and privacy. If we can overcome these challenges, the benefits of digitalization for both animal health and public health and safety could be enormous. We must take the digitalization of animal health seriously and invest in the infrastructure and technology required to manage it because it affects national security.

REFERENCES

Adly I, Sayour HEM, Badawy NM, Ragai H.2013. Evaluation of Real-time Water Quality Monitoring System in Nile Tilapia–lettuce Aquaponic based on wireless sensor network. 6th International Conference of Animal Wealth in Middle East and North Africa, vol 6: (175-192).

Animal Disease Outbreaks and Global Food Security. 2015. Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/3/a-i4434e.pdf

Chanda A, Maghrawy H, Sayour HEM, Gummadidala PM, Gomaa OM. 2020. Impact of Climate Change on Plant Associated Fungi

(Book Chapter), Climate Change Impacts on Agriculture and Food Security in Egypt. p.p. 83-96Springer. doi:10.1007/978-3-03041629-4_5.

Digital Agriculture: Improving animal health, welfare and productivity. 2018. European Commission. Retrieved from https://ec.europa.eu/digital-single-market/en/news/digital-agriculture-improving-animal-health-welfare-and-productivity

Khan AU, Melzer F, Hendam A, Sayour AE, Khan I, Elschner MC, Younus M, Ehtisham-ul Haque S, Waheed U, Farooq M, Ali S, Neubauer H, El-Adawy H. 2020. Seroprevalence & molecular identification of Brucella spp. in bovines in Pakistan - investigating association with risk factors using machine learning. Front. Vet. Sci., (7): 594498

Lee H, Lee H, Lee J, Lee H, Kim J. 2018. Early Detection of Foot-and-Mouth Disease by Infrared Thermography Imaging of Pig and Sheep. Sensors (Basel, Switzerland), 18(6), 1836. doi:10.3390/s18061836

Nour El-Deen SK, Elborai H, Sayour HEM, Yahia A. 2018. Wireless Sensor Network Based Solution for Water Quality Real-Time Monitoring. Egypt. J. Solids, (41): 49-62.

OIE. (2018). OIE Annual Report on antimicrobial agents intended for use in animals: better understanding of the global situation. Paris: World Organisation for Animal Health.

Ragaie HF, Adly I, Sayour HEM, Wilson S. 2017. Remote Control and Monitoring of Fish Farms using Wireless Sensor Networks12th International Conference on Computer Engineering & Systems (ICCES), 19-20 December 2017. doi:10.1109/ICCES.2017.8275287

Rich KM, Perry BD. 2011. The economic and poverty impacts of animal diseases in developing countries: new roles, new demands for economics and epidemiology. Preventive Veterinary Medicine, 101(3-4), 133-147. doi:10.1016/j.prevetmed.2010.07.005

Sayour AE, Sayour HE. 2015. Development and characterization of imprinted polymer hydrogels for molecular recognition of the O -polysaccharide of *Brucella abortus* and *Brucella melitensis*. Conference: First International Scientific Workshop on Biosensors Technology and Molecular Imprinted Polymers: Potential Applications of Theranostics, Food Safety and Environment.

Sayour HEM. 2014. Potential applications of MIP technology in veterinary diagnoses. 8th International Congress on Molecular Imprinting MIP2014 Jiangsu University, Zhenjiang, 212013, P. R. China, 18-21 Sept, 2014.

Sayour HEM. 2015. Biosensors technology and molecular imprinted polymers: Potential applications in theranostics, food safety and environment. Omics group's 4th International Conference and Exhibition on Biosensors & Bioelectronics, 28-30 September 2015, Atlanta, USA. J Biosens Bioelectron, http://dx.doi.org/10.4172/21556210.C1.025.

Sayour HEM. 2017. Tandem mass spectrometry as a tool for tailoring animal disease diagnostics based on biomarker discovery: Molecular imprinting approach. 5th International Conference on Current Trends in Mass Spectrometry and Chromatography J Chromatogr Sep Tech 2017, 8:6 (Suppl). DOI: 10.4172/2157-7064-C1-035 September 25-26, Atlanta, USA. Research & Reviews: Journal of Pharmaceutical Analysis (extended abstract) vol. 8 (3): 2019

Sayour HEM. 2018. Hyphenated Mass Spectrometric techniques for smart materials architecture: Theranostic applications Conference: International Conference on Materials Physics and Materials Science Paris November 2018.

United Nations. 2019. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423). Retrieved from https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf