The Pharma Innovation Journal 2022; SP-11(2): 1293-1297

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(2): 1293-1297

www.thepharmajournal.com
Received: 16-12-2021
Accepted: 18-01-2022

Kailashkumar B
Ph.D. Scholar (Farm Machinery and Power Engineering), Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tamil Nadu, India

SS Sivakumar
Professor and Head, Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tamil Nadu, India

J John Gunasekar
Professor (Bioenergy), Department of Crop Management, Agricultural College and Research Institute, Eachankottai, Thanjavur, Tamil Nadu, India

PK Padmanathan
Assistant Professor (FM), Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tamil Nadu, India

V Alex Albert
Assistant Professor (Seed Technology), Krishi Vigyan Kendra, TNAU, Sirugamani, Tamil Nadu, India

R Ravikumar
Assistant Professor (Mathematics), Department of Physical Sciences and Information Technology, Agricultural Engineering College and Research Institute, Coimbatore, Tamil Nadu

Corresponding Author
Kailashkumar B
Ph.D. Scholar (Farm Machinery and Power Engineering), Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tamil Nadu, India

Nanotechnology in farm machinery: New opportunities and perspectives

Kailashkumar B, SS Sivakumar, J John Gunasekar, PK Padmanathan, V Alex Albert and R Ravikumar

DOI: https://doi.org/10.22271/tpi.2022.v11.i2Sq.10945

Abstract
Agriculture as a source of food is becoming increasingly important in a world of diminishing resources and an ever-increasing global population. It is necessary to utilize future ready solutions like nanotechnology to increase global food production, enhance food quality, and reduce waste for sustainable intensification. The potential uses and benefits of nanotechnology are enormous. Productivity enhancement through nanotechnology-driven precision farming and maximization of output and minimization of inputs through better monitoring and targeted action is desirable. Nanotechnology is the creation of devices and machines on an atomic level which will be a driving force for the next generation. Nano can be technically defined as manipulation of matter with at one dimension sized from 1 to 100 nanometers (0.000000001 m). The nanotechnology revolution had a ground-breaking impact in multidisciplinary fields, and there are likely to be considerable advantages in the field of agricultural engineering in the near future. Nanotechnology is expected to have a massive impact on the world food supply chain. It was found that nanotechnology can impact so many areas of farm machinery, and it has created a more significant impact on the manufacturing and service sectors. The recent advances in nanotechnology-based tools and techniques can address the various problems of conventional agriculture and can revolutionize the industry. In the present scenario, Nanotechnology is used in the manufacturing of agricultural equipment, production of nano-polymer composites, metal nanocomposites, paints, resistivity coatings in machinery, sensors used for precision farming, and lubricants.

Keywords: nano, machinery, agriculture, food, coating, manufacturing

Introduction
About 2 billion people worldwide experience moderate or severe food insecurity (FAO, 2019). The lack of regular access to food puts them at greater risk of malnutrition and poor health. This vastly different world calls for new ways of thinking about food insecurity and its consequences (FAO, 2019). In many developed countries, more than 40% losses of food (cereals, roots and tubers; pulses and oil crops; vegetables and fruit; fish, meat, and dairy) occur at trade and customer stages, while in the case of developing countries, greater than 40% losses of food occur at post-harvest stage and processing point (FAO, 2019; Gustavsson *et al*. 2011) [17]. Predictions show that food demand is likely to rise from 59 to 98% for the world population reaching 9 billion by 2050 (Duro *et al*. 2020) [12]. These issues can be overcome by introducing nanotechnology to improve the crop productivity and nutritional value of the crops (Manjunatha *et al*. 2016) [25]. Nanotechnology is an emerging platform for the transformation and innovations of agriculture systems (Scrinis and Lyons 2007) [38]. Nanotechnology is a unique phenomena enable novel applications in a wide range of fields such as chemistry, medicine, engineering, agriculture and electronics (NNI, 2019). Whereas nanoscience is a study of properties and behavior of condensed materials in nanoscale, natural nanoscale phenomena such as the fascinating field of bio-systems, and investigating the peculiarities of nanosystems (Mansoori, 2005) [26]. Agricultural efficiency, safe water use, soil improvement, distribution of food in stores, and its quality are fundamental factors of securing food that may be improved via advances in nanotechnology research (Ashraf *et al*. 2021; Sastry *et al*. 2011) [7]. Conceptually, nanotechnology may be defined as the ability to create new structures at a minor scale, using tools and techniques that allow the understanding and manipulation of matter at the nanoscale, generally from 0.1 to 100 nm (Zhu, Bartos, and Porro, 2004) [43]. Nano has a growing trend in the production and manufacture of all the equipment used in everyday life related to hard-working conditions, design and durability characteristics of agricultural equipment and one of its areas of application can be in production and manufacturing of agricultural equipment with unique features in different domains (Dehkordi and Keivani 2017)

[11]. Nanotechnology has the potential to reduce failure and damage significantly in the agricultural machinery industry.

Nanotechnology in Machinery Manufacturing

Compared to conventional composites, nanocomposites with improved mechanical properties can be a new approach to lightening and even replacing metal parts in agricultural machinery. Theoretically, these materials can be easily extruded or molded in the final shape, while they have the same strength as the metal and are lighter (Dehkordi and Keivani 2017) [11]. Nanocomposites are more lightweight than standard composites up to around 22% due to the need for lesser reinforcing materials, and therefore the use of nanocomposites in the production and construction of agricultural equipment and machinery is essential (Vatan-Dolat-Xah 2006) [11]. The performance of internal combustion engines can be increased by decreasing the size and weight of the system through Nano-manipulation. Engine blocks, where the heart of the vehicle was only made of cast iron because it could resist the high temperatures and pressures, but with the help of Nanotechnology-specific grades of aluminum replaced the cast iron. This gives the most fuel efficient and durability, even in the aggressive conditions of the engines. Simulation of the basic structure of the engine block architecture results in better heat dissipation, wear, strength at higher temperature conditions. Reducing the flow of heat through the internal combustion engine walls is the main objective of adiabatic engines, also known as low heat rejection engines. Also, these kinds of engines are named coated engines with thermal barriers (Murthy *et al*. 2010) [29]. The use of lesser-weight materials of the structural chassis parts of the vehicle can improve the mileage considerably. Reducing the weight of the machine can increase the fuel efficiency, reduce CO_2 emissions and production cost. It is estimated that by reducing the weight of a component by 10%, there will be a fuel economy of 7% (Margarida *et al*. 2012 and Goyal *et al*. 2014) [28, 35]. The Nano manipulation of the materials can create durable and more substantial parts. The stiffness of the material can be increased by grain size materials without changing the flexibility of the metal.

Nanotechnology in energy sector

The agricultural sector is the second-highest contributor to CO_2 emission after fossil fuel combustion and industrial processes (Anon. 2017) [6]. The fuel crisis is one of the major problems nowadays. Fossil fuel is the most used source of energy in farm tractors and other internal combustion engines. Subsequently, the availability of fuel is gradually getting reduced day by day because it is a non-renewable source. Nanomaterials are being used to build a new generation of solar cells, hydrogen fuel cells, and novel hydrogen storage systems capable of delivering clean energy to countries still reliant on traditional, non-renewable contaminating fuels (Bayda *et al*. 2020). As the next generation of electric agricultural machineries emerging, lengthening battery life is important for increasing performance. The development of lithium-silicon batteries has the capability to boost performance and increase longevity. The silicon nanowires that expand and contract as they absorb and shed lithium ions, the tiny nanostructures with carbon shells protecting lithium-rich silicon cores are used. This combination allows for more efficient energy transfer, and less energy is lost to the environment as heat. Fuel cell is a device that converts fuel directly into electricity in an electrochemical reaction. This is in contrast to most methods of generating electricity, which use the heat from burning fuel to generate electricity mechanically (Tilak and Sivakumar, 2014). Hydrocarbon fuels are the alternative way of energy generation by means of fuel cells. Hydrogen from carbon nanotube is passed over a catalyst to produce hydrogen ions, which are then reattached to oxygen and result in energy production (Pandiyan and Prabaharan, 2020) [16].

Nano Lubricants

Nanoparticles are being used as an additive to enhance the lubricants. Wear and abrasion mechanism are created in contact with two surfaces in the presence of hard particles on one or both tools. The dry roughness of the surface can also be the cause of various types of wear (Rabinowicz and Tanner 1966). The wear depends on the different criteria such as strength, geometry, and surface parameters. The mechanisms by which oils containing nano-additives reduce frictional wear under boundary lubrication are the colloidal effect, rolling effect, small-size effect, protective film effect, and third body effect (Li *et al*. 2006) [24]. Present lubricant formulators are looking to improve fuel economy through less viscosity engine oils and adopting new and more effective friction modifiers (Jao, Devlin, and Aradi 2014) [21]. The friction and wear of the worn surfaces are a principal cause of energy dissipation in automobile engines. The tribological quantity of Graphene-based nano lubricants improves the anti-friction and anti-wear properties by 29–35% and 22–29%, respectively, during the boundary lubrication system (M K Ahmed Ali *et al*. 2018) [4].

In tribological test, $Al2O_3/TiO_2$ was added to engine oil (5W-30) as friction and wear modifiers with a grain size of 8–12 nm, showing a friction reduction of 50% and the wear rate of the piston ring enhanced by 40% compared with the base oil (Ali *et al*. 2016) [2]. Granular nanomaterials are cohesion-less strong particles that sufficiently maintain the spherical geometry under pressure and accommodate surface velocity differences through rolling and shearing (Deepika, 2020) [10]. With the recent advancements of nanotechnology, nanomaterials have emerged as a potential source to enhance the tribo-performance of different lubrication systems. Inorganic nanoparticles include pure metals, metal-oxides, metal-sulfides, metal-fluorides, etc. Metal nanoparticles have practical limitations of oxide formation in open environments. The ability to improve load-carrying capacity by adding nanoparticles depends upon the proper combination with the type of lubricant. An increase in consistency of the lubricants after the addition of nanoparticles resulted in the better performance of the machine components. The complications of using nanoparticles as additives include the method of adding and agglomeration of nanoparticles in the lubricants. In order to resolve this, the Nanoparticles should be uniformly dispersed throughout the lubricant. If the concentration of the additives is increased, the tribological performance of lubricants deteriorates and forms microclusters due to their tendency to get agglomerated.

Nanocoatings

Several studies have shown that the addition of nanoparticles in coatings extremely improves the scratch and abrasion resistance over a longer period, but there is a necessity to select the right proportion of nanoparticles in polymer coatings (Ching, Y.C and Syamimie, 2013; Khanna, 2008) [8, 23]. Nano-coating can be applied in many ways, including

chemical vapor phase deposition, physical vapor phase deposition, electrochemical deposition, Sol-gel methods, electro-spark deposition, and laser beam surface treatment. Nanoparticles such as ZrO_2, AlOOH, SiO_2 have been embedded in UV-curable lacquers, resulting in improved abrasion resistance. Nano layers of the filters are being applied to the surface of the machines to cover it from the harsh environments and self-cleaning. It helps to repel the dirt and dust, which enables the rustproof. Structures such as nanocarbon, nanotubes, nanofibers, and graphite structures are densely packed that act as a penetrative and, at the same time, it can be used to produce nano coatings and paints. The resulting nano paints and coatings possess excellent qualities such as increased scratch resistance, increased hardness, mould and bacteria resistance (Yang and Li, 2018) [31]. Nanostructured nickel coatings which have a grain size of about 100 nm and are produced by electroplating method, have wear resistance is about 100 to 170 times than nickel coatings with grain size of 100 micrometers. The coefficient of friction is about 40 to 50 percent less than conventional nickel coatings (Ebrahimi *et al*. 1999) [13]. Ceramic coatings of nanoparticles contribute to high thermal stability and erosion resistance in engine parts (Asadi-Fard 2017). The coatings were made by pulse electroplating could increase abrasion resistance relative to 55.83%. The lesser average sizes of grains of nickel Nano-coatings of the structure, the more the hardness and consequently, the more wear resistance (Abed N *et al*., 2019) [1]. Copper and nickel nanocatalyst coatings were applied on the piston top to reduce the hydrocarbons emissions by 64%, smoke level reduced up to 21%, NOX emissions also reduced up to 45%, SFC and brake thermal efficiency and were improved in coated pistons (Ramalingam, Rajendran, and Ganesan 2016). Moisture change can affect the wear resistance of the nanostructured materials in different orders (Czichos and Misra, 1978). When a specific amount of layered double hydroxide nanoparticles is dispersed with the paint solution, it improves the char formation and fire-resistant properties of the coating. The performance of anticorrosive polymer nanocomposites coatings were evaluated in the marine environment. Three steel surfaces named as E32 uncoated steel; E32 with primer (painting) and E32 with primer + TiO_2 nanoparticles were prepared to evaluate their performance against corrosion in seawater. It was observed that the corrosion rate was very high in the case of E32 uncoated steel. Obstinately, E32 with primer + TiO_2 nanoparticles surface layer showed a tremendously lower corrosion rate which indicated that nanoparticle coatings have higher corrosion resistance in seawater (Mardare and Benea, 2017) [27].

Nanosensors

Precision farming reduces contaminants, pollutants, and agricultural waste in the environment. Thus, this technology is an eco-friendly and sustainable practice (Shafi *et al*. 2019) [39]. The concept of precision farming deals with less input to obtain the maximum output. For achieving a better yield, the data collected from the field must be processed. Nanoparticle mediated material delivery to plants and advanced biosensors for precision farming is possible only by nanoparticles or nanochips. The vital role of nanotech-based agricultural machinery and equipment is having a programmed sensors coupled to GPS devices for real-time control. Nanosensors can be distributed across the field to control and standardize the soil conditions and crop growth. With the help of Nano-tubes, Nanosensors can be manufactured, which are tiny and can measure even micro molecules (Dehkordi and Keivani, 2017) [11]. Nanosensors-based innovative delivery systems could help in the efficient use of natural resources like water, nutrients, and agrochemicals by precision farming (Rai *et al*. 2012) [33]. Various biosensors are used for diagnosis, controlling disease and pest attacks in this field. In that, Green seeker is one of the Nano sensors which works on the principle that healthy crops absorb more red light and reflect more infrared light, form that it actually measures the amount of biomass of the plants. Due to their fluorescent properties and broad-spectrum, quantum dots are helpful in the detection of microbes as well as in the prevention of plant diseases (Chiranjeeb and Senapati, 2020) [9].

Nanotechnology in tire manufacturing

A typical farm tractor tire tread consists of natural and synthetic rubber, fillers, additives, linkers, and reinforcement (steel, textile, or nylon cord). The performance of the tire is based on its rolling resistance, abrasion resistance, and wet traction. A good tire should have low rolling friction, but at the same time, it should have a good grip. The properties of tires mainly depend upon the chemical and physical interactions between the filler material and the rubber. The rubber mixtures contain carbon black, soot, silica, and organosilica to improve their properties and lifetime (Mathew *et al*. 2018) [19]. Tires enhanced with CNT (carbon nanotubes) have improved mechanical properties, such as tensile strength, tear strength, and hardness of the composites. Polymerization is one of the most common methods to incorporate CNTs into a polymer matrix. The behavior of a burdened tire during its deformation is difficult due to the united contributions of the structural components of tread rubber and the air contained within it (Anifantis, Cutini, and Bietresato 2020) [5]. The safety and durability of tires can be improved by adding appropriate nanoparticles in rubber composites (Alkhazraji 2018) [4]. The nanocomposite in the tire increases wear resistance, strength, and elegance of the tire. All of these factors provides a high-quality product that can last longer on both wet and dryland conditions for tractors and combines. Incorporating the nanoparticles to the tire, the quantity of rubber required for the tire is reduced, and the tire becomes lighter in weight with high durability (Dehkordi and Keivani 2017) [11]. On the other hand, adding CuO nanoparticles in very small amounts with the enclosed tire air decreases the hysteresis losses and improves its performance significantly. Three different composites of CuO (copper oxide) nanoparticles were experimented with deflection test by loading and unloading the tested tire while resting on a firm surface at three different inflation pressures and found that higher hysteresis losses were at tire inflation pressure at 20 psi (El-Zomor 2019) [15].

Conclusion

This paper is based on the establishment of essential awareness about nanotechnology in farm mechanization and their projections in the near future with reference to the current situation around the world. Nanotechnology will have a vital role in improving the agricultural sector to increase food production and productivity. The availability of valuable nanoparticles and safety assessments of their field application is needed for ensuring food and nutritional security of the ever-increasing world population in a changing climate scenario (Rana *et al*. 2021) [34]. Agricultural machinery

manufacturers must pay attention to the use of this technology to enhance their products and satisfy farmers, and in the long run, it has a tremendous effect on the sale of their products.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Abed, Niloofar, Mohammad Ebrahim Bahrololoom, Mehdi Kasraei. "The Effect of Nano-Structured Nickel Coating on Reducing Abrasive Wear of Tillage Tine." Journal of Nanotechnology Research. 2019;1(2):59-74.
2. Ali MKA, Xianjun H, Mai L, Bicheng C, Turkson RF, Qingping C. Reducing frictional power losses and improving the scuffing resistance in automotive engines using hybrid nanomaterials as nano-lubricant additives. 2016:364-365, 270-81.
3. Ali, Mohamed Kamal Ahmed, Hou Xianjun, Mohamed A, Abdelkareem A, Gulzar M, Elsheikh AH. "Novel Approach of the Graphene Nanolubricant for Energy Saving via Anti-Friction/Wear in Automobile Engines." Tribology International. 2018;124:209-29.
4. Alkhazraji, Ahmed N. Enhancement of Mechanical Properties and Handling Characteristic of Tire Rubber Using Different Percentage of Nano Aluminum Oxide and Carbon Black." SMR 20:100, 2018.
5. Anifantis, Alexandros Sotirios, Maurizio Cutini, Marco Bietresato. "An Experimental–Numerical Approach for Modelling the Mechanical Behaviour of a Pneumatic Tyre for Agricultural Machines." Applied Sciences. 2020;10(10):3481.
6. Anon. Global Greenhouse Gas Emissions Data EPA, 2017.
7. Ashraf SA, Siddiqui AJ, Abd Elmoneim OE, Khan MI, Patel M, Alreshidi M *et al*. Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. Science of the Total Environment, 144990, 2021.
8. Ching YC, Syamimie N. Effect of Nanosilica Filled Polyurethane Composite Coating on Polypropylene Substrate. J Nanomater, 2013, 1-8.
9. Chiranjeeb, Senapati. Role of Nanotechnology in Precision Farming. Research Today. 2020;2(7):584-586.
10. Deepika Nanotechnology implications for high performance lubricants. SN Appl. Sci. 2020;2:1128. https://doi.org/10.1007/s42452-020-2916-8
11. Dehkordi, Amin Lotfalian, Farideh Keivani. "Applications of Nanotechnology for Improving Production Methods and Performance of Agricultural Equipment." Vatan-Dolat-Xah, Ja'far. 2006. "Nanotechnology, Basic Science, and New Technology." 2017;9(2):102-6.
12. Duro JA, Lauk C, Kastner T, Erb KH, Haberl H. Global inequalities in food consumption, cropland demand and land-use efficiency: A decomposition analysis. Global Environmental Change. 2020;64:102124.
13. Ebrahimi F, Bourne GR, Kelly MS. Mechanical properties of nanocrystalline nickel produced by electrodeposition Nanostructured Materials. 1999;11:343-350.
14. EG&G Services Inc. Fuel Cell Handbook, 5th ed., U.S. Department of Energy Office of Fossil Energy National Energy Technology Laboratory Inc.: Morgantown, West Virginia, USA, 2000.
15. El-Zomor HM. "Reducing Tyre Hysteresis Losses Using CuO Nanoparticles." International Journal of Vehicle Structures & Systems. 2019;11(5):471-75.
16. Karthik Pandiyan G, Prabaharan T. Implementation of nanotechnology in fuel cells, Materials Today: Proceedings, 2020 https://doi. org/10.1016/j.matpr.2020.01.368
17. Gustavsson J, Cederberg C, Sonesson U, Van Otterdijk R, Meybeck A. Global food losses and food waste, 2011.
18. Sitompul J, Zhang H, Noguchi R, Ahamed T. Optimization study on the design of utility tractor powered by electric battery. The 3rd International Symposium on Agricultural and Biosystem Engineering, IOP Conf. Series: Earth and Environmental Science, 2019, 355 012058 IOP Publishing doi:10.1088/1755-1315/355/1/012058
19. Mathew J, Joy J, George SC. Potential applications of nanotechnology in transportation: A review, Journal of King Saud University – Science, 2018. doi: https://doi.org/10.1016/j.jksus.2018.03.015
20. Zhou J, Yang J, Zhang Z, Liu W, Xue Q. "Study on the structure and tribological properties of surface-modified Cu nanoparticles," Mater. Res. Bull. 1999;34(9):1361-1367,
21. Jao, Tze-chi, Mark T, Devlin, Allen Aradi A. "Nanoparticle Additives and Lubricant Formulations Containing the Nanoparticle Additives", 2014
22. Karan Tilak, G Siva Kumar. Nanotechnology fuel cells. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Ver. III 2014 Jul-Aug;11(4):04-08 www.iosrjournals.org
23. Khanna AS. Nanotechnology in High Performance Paint Coatings A.S. Asian J Exp. Sci. 2008;21:25-32.
24. Li, Xiaohong, Zhi Cao, Zhijun Zhang, Hongxin Dang. "SurfaceModification in Situ of Nano-SiO2 and Its Structure and Tribological Properties." Applied Surface Science. 2006;252(22):7856-61.
25. Manjunatha SB, Biradar DP, Aladakatti YR. Nanotechnology and its applications in agricul-ture: a review. J Farm Sci 2016;29(1):1-13
26. Mansoori GA. Principles of Nanotechnology. World Sci Pub Co, Hackensack, NJ, 2005.
27. Mardare L, Benea L. Development of Anticorrosive Polymer Nanocomposite Coating for Corrosion Protection in Marine Environment. In IOP Conference Series: Materials Science and Engineering; IOP Publishing: Bristol, UK, 2017.
28. Margarida Coelho C, Guilhermina Torrao, Nazanin Emami, Jose Gracio. Nanotechnology in Automotive Industry: Research Strategy and Trends for the Future Small Objects, Big Impacts. Journal of nanoscience and nanotechnology, 2012;12:1-10.
29. Murthy PVK, Murali Krishna MVS, Sitarama Raju A, Vara Prasad CM, Srinivasulu NV. "Performance Evaluation of Low Heat Rejection Diesel Engine with Pure Diesel." International Journal of Applied Engineering Research. 2010;1(3):428.
30. National Nanotechnology Initiative (NNI) Available online: www.nano.gov.
31. Qing Yang, Liang Li. Advanced Coating Materials. United Kingdom: Wiley, 2018.
32. Rabinowicz E. Friction and Wear of Materials". A Wiley-interscience publication. 2nd Edn, 1995, 128-132.
33. Rai V, Acharya S, Dey N. Implications of nano

biosensors in agriculture, J Bio mater Nanobiotchnol. 2012;3:315- 324.
34. Rana, Ruhul A, Md. Siddiqui N, Milan Skalicky, Marian Brestic, Akbar Hossain, Emrul Kayesh, *et al*. "Prospects of Nanotechnology in Improving the Productivity and Quality of Horticultural Crops" Horticulture. 2021;7(10):332. https://doi.org/10.3390/horticulture7100332
35. Rohit Goyal, Manish Sharma, Umesh Kumar Amberiya, Innovative Nano Composite Materials and Applications in Automobiles. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, 2014, 3(1).
36. Nam SR, Jung CW, Choi CH, Kang YT. "Cooling performance enhancement of LED (light emitting diode) packages with carbon nanogrease," Energy. 2013;60:195-203,
37. Sastry K, Rashmi HB, Rao NH. Nanotechnology patents as R&D indicators for disease management strategies in agriculture. Journal of Intellectual Property Rights. 2010;15:197-205.
38. Scrinis, Gyorgy, Kristen Lyons. "The Emerging Nano-Corporate Paradigm: Nanotechnology and the Transformation of Nature, Food and Agri-Food Systems." The International Journal of Sociology of Agriculture and Food. 2007;15(2):22-44
39. Shafi U, Mumtaz R, García-Nieto J, Hassan SA, Zaidi SAR, Iqbal N. Precision agriculture techniques and practices: from considerations to applications. Sensors. 2019;19(17):3796
40. Uflyand IE, Zhinzhilo VA, Burlakova VE. Metal-containing nano-materials as lubricant additives: State-of-the-art and future development. Friction. 2019;7(2):93-116.
41. Bakunin VN, Suslov AYY, Kuzmina GN, Parenago OP, Topchiev V. "Synthesis and application of inorganic nanoparticles as lubricant components--a review," J. Nanoparticle Res. 2004;6(2):273-284,
42. Grove WR. Esq. M.A. F.R.S. LXXII. On a gaseous voltaic battery, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science. 1842;21:140, 417-420, DOI: 10.1080/14786444208621600
43. Zhu, Wenzhong, Peter Bartos JM, Porro A. "Application of Nanotechnology in Construction." Materials and Structures. 2004;37(9):649-58.
44. FAO. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction, 2019. Rome. Licence: CC BY-NC-SA 3.0 IGO
45. Sastry RK, Rashmi HB, Rao NH. Nanotechnology for enhancing food security in India. Food Policy. 2011 Jun 1;36(3):391-400.
46. Bayda S, Adeel M, Tuccinardi T, Cordani M, Rizzolio F. The history of nanoscience and nanotechnology: From chemical–physical applications to nanomedicine. Molecules. 2020 Jan;25(1):112.
47. Tilak K, Kumar D. GS. Nano-Technology Fuel Cells. IOSR J Mech Civ Eng. 2014;11(4):04–8.
48. Asadi-Fard, Reza. "A Brief Glance at Some Applications of Nanotechnology. 2004." Dehkordi AL, Keivani F. 2017, 102–6.
49. Ramalingam, Senthil, Silambarasan Rajendran, Pranesh Ganesan. "Performance Improvement and Emission Control in a (JAAR) Volume: 26 (2) 45 Direct Injection Diesel Engine Using Nano Catalyst Coated Pistons." Biofuels. 2016;7(5):529-35.
50. Czichos Horst, Misra A. "Tribology: A Systems Approach to the Science and Technology of Friction, Lubrication and Wear (Tribology Series, 1).", 1978.