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Nanotechnology - The Mantra of Present and Future in Agriculture and Food

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Abstract

The benefit of use of nanotechnology in agriculture is evident by the increase in productivity, decrease in residue, production of more safe and nutritious food. It can thus be used as an effective tool to meet the needs of growing population, combat hunger. The combination of nanotechnology with Bio technology further widens its avenue and scope. It is still at initial stage of research and we do not yet have any specific regulation for assessing the toxicity or environmental impact of nanoparticles. It is a challenge to Government and industry as they have to ensure the acceptance of Nano foods. The scope of the technology is still not yet fully exploited and consumers are generally in awe or skeptical about it. Mandatory testing of Nano modified food is needed before they are allowed into the market. As in case of GM crop concern has arisen over the use of Nano particles in food. It has the potential to change the way things are produced and processed thus reduce the hazardous side effects. No adverse effect has been reported so far for the commercially available fluorescent nano particle. Though many questions still remain unanswered and the potential of nanotechnology is yet to be exploited fully. Yet keeping in mind the scope and prospect of nanotechnology, it can indeed be said to be the future mantra of agriculture and food.

Keywords: *Nanotechnology; Agriculture; Food; Applications*

Introduction

Nano comes from the Greek word for dwarf and nanoparticles are characterized as those with the particle size of a hundred nano meters, thus this unique phenomenon enables noble application and benefits especially in agriculture & allied field. We are well accustomed to the proverb small is beautiful and since this is a very new field and the potential of resource is wide, a new range of nano scale techniques, materials and products are currently being developed. Though the development is at the grass root level across all sectors viz; Agri-food business, food manufacturing, processing, including food packaging, retailing, Agri irrigation, precision farming, plant &animal health, water management.

Nanotechnology has offered a range of benefits across the Agri-food system like increasing productivity. Environmental benefits include reduced chemical use thus decreasing residue and pollution and hence more nutritious and safe food. Nanotechnology is being considered as a potential sector to help in meeting the needs of growing population, combating hunger and also meeting the challenges of climate change and other ecological disturbances [1].

Nanotechnology is projected to impact the food industry mainly through the creation of nano-sized materials with novel properties, the development of novel processing methods, products and improvements in food safety and bio security as shown in Figure 1 [2].

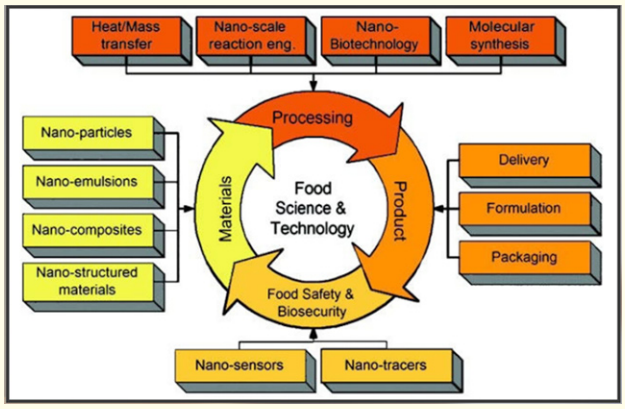


Figure 1: *Nanotechnology in food science and technology [2].*

The global population presently is nearly 6 billion & population growth rate is nearly 2% .The developing countries faces the challenges of food shortages, while in developed countries food is surplus. We have to find ways to combat hunger and to feed the growing population. Research is focused on developing drought resistant and pest resistant crop for maximizing yield. Nano scale technologies are so powerful that one cannot imagine at present especially its strength in increasing agricultural food production, distribution and consumption. Nano packaging innovations, for long distance transportation; improve shelf life and nutritional benefits, water management etc. We cannot yet anticipate that Nanotechnology will end up making breakthrough in ways that we can harness its power towards useful ends. Some of Important sectors in agriculture and related aspects are benefitted by the application of nano technology especially for the benefits of mankind.

Precision Farming

The concept of precision agriculture has been around for some time now. It has been defined as a comprehensive system designed to optimize agricultural production by carefully tailoring soil and crop management to correspond to the unique condition found in each field while maintaining environmental quality [3]. Precision farming has been a long-desired goal to maximize output (i.e. crop yields) while minimizing input (i.e. fertilizers, pesticides, herbicides, etc.) through monitoring environmental variables and applying targeted action. The technologies proposed at this point comprised of three aspects: (a) Remote Sensing (RS), (b) Geosynchronous Positioning System (GPS) and (c) Geographical Information System (GIS). By using centralized data to determine soil conditions and plant development, seeding, fertilizer, chemical and water use can be fine-tuned to lower production costs and potentially increase production- all benefiting the farmer [4]. The most important step in precision agriculture is the generation of maps of the soil with its characteristics. These included grid soil sampling, yield monitoring and crop scouting. RS coupled with GPS coordinates produced accurate maps and models of the agricultural fields. Precision farming can also help to reduce agricultural waste and thus keep environmental pollution to a minimum. Although not fully implemented yet, tiny sensors and monitoring systems enabled by nanotechnology will have a large impact on future precision farming methodologies. One of the major roles for nanotechnology-enabled devices will be the increased use of autonomous sensors linked into a GPS system for real-time monitoring. These nano-sensors could be distributed throughout the field where they can monitor soil conditions and crop growth. Wireless sensors are already being used in certain parts of the USA and Australia.

Plant and Animal Health

Nanotechnology can help in diagnosis, treatment, and monitoring of diseases of crops and livestock to ensure timely intervention when necessary. Nanoparticles have been designed to adhere irreversibly to target pathogenic bacteria, reducing infectivity of food borne entero pathogens in poultry products [5]. Thin films and nano emulsions have been used to prevent adhesion of bacteria on

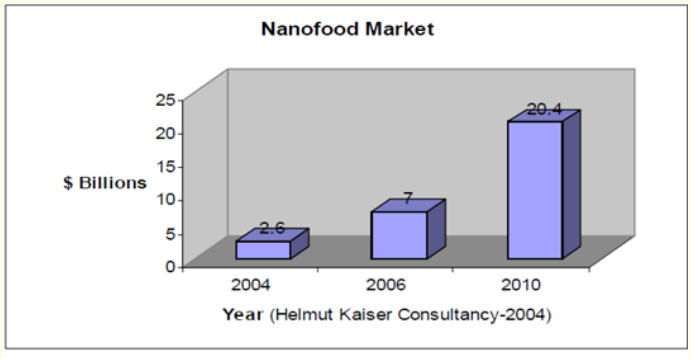
surfaces of equipment. Additionally, selected nanoparticles of magnesium oxide and zinc oxide were found to be highly effective at destroying microorganisms; coatings made from these nonmaterial's can impart anti-microbial and biocidal properties on surfaces. This application has important uses at food production sites, in particular abattoirs and meat processing plants [6]. Nano shells with attached antigens were designed to seek out cancer cells and bind with them; when illuminated with infrared light, the nanoshells are heated, raising the temperature of the bound cancer cells and destroying them [7]. Non-invasive bio analytical nanosensors are being developed that could be placed in an animal's salivary gland to detect the presence of pathogenic bacteria and viruses before these had a chance to multiply and develop disease symptoms that become visible to the farmer. These smart nanodevices will act both as a preventive and an early warning system and can also be used to deliver drugs and vaccines in a controlled and targeted manner. The combo of nanotechnology with biotechnology further widens the avenues and scope of using plant and animal breeding including new techniques for the development of genetically engineered crops. Researchers are now using nanoparticles, nanofibres and nanocapsules to introduce foreign DNA and chemicals into cells [8]. The emerging field of synthetic biology offers a more radical approach to genetic engineering and plant breeding [9].Thus nano–genetically engineered seeds could therefore facilitate the further technological and corporate integration of seed, chemical and other agricultural inputs.

Water Management

It is a paradoxical situation that one-third of the globe constitutes of water and stills the world struggles with this basic necessity of life–water. Supply of clean water, safe water, potable water and that too adequately and on a regular basis, are the main issues faced by the people. The worst part is that the situation is predicted to get further grim with the resources depleting and the population pressure increasing. The increasing ecological imbalance on one hand and increased use of water further aggravate the problem. Solutions are being found out by use of science and technology for water harnessing, management and conservation. Application of Nanotechnology to these conventional solutions in the first stage and for finding new solutions subsequently is a ray of hope in this area. Nano technology not only assures better quality but also with lesser energy consumption and hence at a much lower cost.

Nanotechnology in the Food Market

Nanotechnology is the new industrial revolution and both developing and developed countries are investing in this to secure a market share. USA has invested 3.7 million USD since last four years followed by Japan 750 million and European Union 1.2 billion. In Asia China, India, South Korea and Thailand are also investing in this technology focusing on its use on agriculture and food industry. Helmuth Kaiser Consultancy had predicted that nano-food market will surge dramatically [10].



World Nanofood market

Figure 2

Increase in population brings the challenge of producing healthy and safe food. The change in weather pattern is further detrimental. Nanotechnology has the potential to revolutionize the agriculture and food industry with new tools for molecular treatment of disease, early detection of disease and enhancing the scope of plants ability to absorb nutrients. Smart sensors and smart delivery system will

help in combating virus and other pathogen. Nanostructure catalyst will increase efficiency of pesticides and herbicides allowing lower doses to be used. Thus this will protect the environment by reducing pollution.

Another agricultural methodology widely used today in USA, Europe and Japan is called CEA (Controlled Environment Agriculture). Plants are grown in a controlled environment and thus provide an excellent platform for introduction of nanotechnology in agriculture. Nanotechnological devices could improve ability to determine best time for harvest of the crop, vitality and detection of pest and pathogen infestation.

Precision farming aims at maximizing crop yields while minimizing use of fertilizers, pesticides and herbicides. Thus it concentrates on targeted delivery. It uses computers; global satellite positioning systems and remote sensing devices thus determines whether the crops are growing at maximum efficiency. This can be tuned to lower production costs and thus increase the farmer's profit. It can also help to reduce agricultural waste and thus keep environmental pollution to minimum.

One of the major roles of nanotechnology device will be increased use of autonomous sensors linked to GPS system for monitoring. These nanosensors are distributed throughout the field where they monitor soil condition and crop growth. Wireless sensors are being used in parts of USA and Australia .In California vineyards, Wi Fi systems have been installed with the help of IT Company. Though the initial cost of installing this is very high it is justified by the high price of wine due to harvesting of grapes at the optimum ripening. Nanosensors are also being used by Honeywell to monitor grocery stores in Minnesota. It helps the shopkeepers to detect food which has passed their expiry date and also to issue a new purchase order.

Smart Delivery Systems

Nanoscale devices with novel property could be used to identify plant pest and disease infestation even before they become visible to the farmer. These devices will alert the farmer early about the problem and can also be used to deliver chemicals in a controlled and targeted manner.

Encapsulation and controlled release method have bought a revolution to use of pesticides and herbicides. Formulations with nanoparticles (100-250 nm) size dissolve readily in water and thus increasing their activity. Syngenta is using nanoemulsion in its pesticide product Karate Zeon is a quick release micro encapsulated product containing Lambda –cyhalothrin which breaks open on contact with leaves (http://www.syngentacropprotection.com/karate-with-zeon-technology-insecticide?tab=details). Research is also going on to make plant use water, pesticide and fertilizer more efficiently and to reduce pollution thus making it more environmentally friendly.

One of the first nano industrial applications is the development of nano pesticides. These are pesticides that contain Nanoscale chemical toxins. These formulations offer a range of novel properties such as increased toxicity, stability and higher dissolving power in water compared to large-scale molecules of the same toxin. Furthermore nano encapsulation of pesticidal toxins offers possibility of controlled and targeted release of pesticides example in alkaline environment of certain insect's digestive system and under specific moisture and heat levels [11]. Due to the targeted delivery of nano pesticides it can result in the reduction in the volume of chemical pesticide applied in specific situations and thus reducing input cost and environmental pollution [12].

On the other hand nano scale pesticide with the increased dissolvability unleashes a new range of possible health and environmental hazards. Presently there is an absence of labeling for Nanoscale chemicals [13]. There is still an ample scope of research in these areas and new strategies and policies needs to be formulated.

In the area of analysis and detection introduction of bio- sensors will help in detection of surface and airborne pathogens. The bio sensors are composed of a biological component linked to a tiny transducer. They detect changes in cells and molecules even in low concentrations. With the increase in concentration of bacteria in a particular food strong signal will be produced indicating that the food is not safe for consumption.

Quantum dot conjugates CTB- Cholera toxin subunit B for labeling mammalian cells. The conjugates were initialized by all tested cell lines into small vesicles dispersed throughout the cytoplasm. Although a large proportion of CTB conjugates eventually also accumulate in perinuclear endosomes, this accumulation requires several days. CTB conjugates are a practical alternative to ployarginine conjugates for the general labeling of the mammalian cells [14].

Fluorescent labeling of cells helps us to track movement, cell division & cell interaction *in vitro* and *in vivo*. Cell labeling was originally reported by using quantum dot conjugates. Both the groups stated that the excellent fluorescent properties of quantum dots (brightness, choice of many emission maxima, chemical stability and photo stability) makes it a very good candidate for cell labeling especially cell tracking over a long period of time [15,16].The use of polyarginine- conjugated quantum dots was developed as a general cellular label. These quantum dots are absorbed by the cell very rapidly [17].

Other Developments in Agricultural Sector Due To Nanotechnology

Increase in population brings the challenge of producing healthy and safe food. The change in weather pattern is further detrimental. Nanotechnology has the potential to revolutionize the agriculture and food industry with new tools for molecular treatment of disease, early detection of disease and enhancing the scope of plants ability to absorb nutrients. . Smart sensors and smart delivery system will help in combating virus and other pathogen. Nanostructure catalyst will increase efficiency of pesticides and herbicides allowing lower doses to be used. Thus this will protect the environment by reducing pollution.

Another Agricultural methodology widely used today in USA, Europe and Japanese called CEA (Controlled Environment Agriculture). Plants are grown in a controlled environment and thus provide an excellent platform for introduction of nanotechnology in agriculture. Nanotechnological devices could improve ability to determine best time for harvest of the crop, vitality and detection of pest and pathogen infestation.

Nanotechnology can be used to clean groundwater. Agronide an US company is using 2 nm dia Aluminum oxide nanofibres as water purifier. These fibers when used to make filters can remove virus, bacteria and protozoa cysts from water. Research at center for Biological and Environmental Nanotechnology has shown that Nanoscale iron oxidized particle is extremely effective at binding and removing arsenic from groundwater.

Potentized drugs significantly increased plant growth, chlorophyll protein and water content in the leaves as compared to the control. ccc30 (nano) was found to be more effective than ccc30. Potentized drugs are thought to initiate their action on the integral membrane proteins of the leaves and modulate cell physiology towards growth [18].

Research on nano particles & insect control should be geared towards introduction of faster and eco friendly pesticides in future [19]. Leading chemical companies should focus on formulation of nanoscale pesticides for delivery into target host tissues through nano encapsulation.

Nanotechnology benefits are enormous including increasing agricultural productivity, slow and efficient release of water & fertilizer, nanocapsules for herbicide delivery and nanosensors for pest detection [20-22]. With nano fertilizers emerging as alternatives to conventional fertilizers, buildup of nutrients in soil and contamination of drinking water may be eliminated [23,24].

Nano Engineering of Functional Foods

In food manufacturing sector nanotechnology can contribute a lot. Nano engineering can lead to development of cheap and processed food. It is used to modify food flavor and texture, speed of processing, shelf life, nutritional profile and heat tolerance. Nanotechnology enables introduction of new traits into food. Food ingredients were developed which were able to produce the creamy taste and structure of full fat products as this will help in enhancing the flavor of low-fat ice cream and spreads [25].

Encapsulation of cucurmin the chemical found in turmeric and possessing antitumor and anticarcinogenic properties has increased the bioavailability of this compound [26]. To protect micronutrient from degradation during manufacturing and storage, nano

Cochleate nutrient delivery system has been developed [25]. It also holds the promise of enabling to change the nutritional profile of food in response to individual allergy, dietary needs or preferences [8].

While studying the health risk of nanoscale food components, nanoparticles version of food additives titanium oxide and silica dioxide that has been approved as GRAS (generally recognized as safe) by US Food and drug administration but there is already sufficient scientific evidence indicating that these nanoparticles are cytotoxic and adding them to food has been done without proper testing [27]. The science of Nanotechnology has the ability to work at the atomic, molecular and sub molecular levels in order to create and use material structures, devices and systems with new properties and functions [28].

Food Packaging and Supply Chain Monitoring

The use of nano materials for food packaging poses health and environmental hazards, as these materials may migrate from packaging into food and thus increase the possibility of nano material ingestion [11, 25]. Furthermore packaging containing nano sensors will change color once the food begins to spoil or if there is microbial contamination. Nanoscale barcodes and monitoring device are also being developed and commercialized. These include nanoscale radio frequency, identification tag (RFID) that will be able to track containers of individual food items.

On one hand nano pesticide will allow more targeted and reduced use of chemical input on farms, it may also facilitate overall expansion of large-scale and resource intensive system of farming, food manufacturing and distribution and ecological problems associated with them.

Developing smart packaging to optimize shelf life has been the goal of many companies. These packaging system alert customers if the food is contaminated or if it is due expiry date, it responds to environmental conditions (e.g. temp and moisture changes). It also alerts customers if the food is spoiling. Nanotechnology can also provide solutions for improving mechanical and heat properties, developing antimicrobial and antifungal surfaces. Today consumers demand much more from packaging in terms of protecting the quality, freshness and safety of food. Kraft food along with Rutgers University in US is developing an "electronic tongue" for inclusion in packaging. This contains an array of nanosensors which detect gases released by food as it spoils thus alerts us if the food is not fresh.

Bayer polymers developed Durethon KU2-2601 packaging film which is lighter, stronger and more heat resistant. This prevents the contents from drying out. The new film is enriched with numerous number of silicates Nano particle. These reduces the entrance of oxygen and other gases and exit of moisture thus preventing food from spoiling (Nanoparticles make Durethane films airtight and glossy , Bayer polymers) .

Nanotechnology can offer improvements in sensitivity of detecting contaminated food. Agronmicron has developed Nano Bioluminescence detection spray which contains luminescent protein which binds to surface of microbes such as Salmonella and *E. coli*. It emits a visible glow thus allowing early detection.

Nanotechnology is used in monitoring and tagging of food items. RFID (Radio frequency Identification) is used in food monitoring in shops for improving supply chain efficiency. Aim to produce nanomaterials with functional properties along with nanosensors and nanofludic technology to be applied in food science. It also aims in producing intelligent packaging materials making it possible to monitor the condition of the products during transportation.

Food Processing

Nanotechnology can also help in development of functional and interactive foods which will deliver nutrients depending on body`s need. Nanocapsules are being developed which can be incorporated into food to deliver nutrients. One of the leading bakeries developed bread containing tuna fish oil (a source of omega 3 fatty acid) which breaks open only when it reaches the stomach.

A number of companies are researching additives which are absorbed by body and can also increase shelf life. Bio-detecting science International have developed Nanocochleates which are 50 nm nanoparticles and can be used to deliver vitamins, Lycopene and omega3 fatty acid more efficiently without effecting color and taste of food.

The prospect of nanostructured materials in use of devices for pollution sensing, treatment and remediation are being considered. Nanoparticles for pollution prevention through different synthesis are also being explored [29].

Food Manufacturing and Processing

Nanotechnology can be applied in the food industry through precise manipulation of food molecules to create healthier, tastier, and safer food products. Nanoscale materials and techniques have been used in the development of novel and functional foods and in safe processing and handling of food [30]. Nanotube membranes were used in the separation of food biomolecules with functional value (e.g., proteins, vitamins, minerals, and flavor) [31]. Nano-based filters were also used for removing undesirable compounds from foods and beverages as well as in the purification of biofuels (i.e., ethanol). Nanoparticles are also being used to advance the concept of functional, 'on-demand' foods, wherein nanocapsules store flavors and nutrients inside food and are released at designated organs in the body when needed by the consumer [30]. Nano-encapsulation of nutrients is also being looked at as a means to deliver more efficiently to cells or organs those nutrients such as vitamins, omega fatty acids or compounds that are degraded by normal digestive processes. Nanospheres can be used to encapsulate functionalized DNA fragments and can be effective delivery vehicles for oral immunization to treat food allergies [32].

Nano Technology and Environment

The subject of 'Global Warming' itself is generating a lot of heat now a day. Having struggled with the issue of ozone layer depletion in the last decades, the world is now facing the challenge of global warming and resultant climate change. It is said 'environment is not what we inherit from our ancestors; we borrow it from our future generations.' We have already started facing the consequences of reckless use of natural resources leading to ecological imbalance. Thus, to hand over to our future generations the same level of environmental quality which we are presently enjoying is becoming difficult day by day. Nanotechnologies are being used to harness the self- assembling properties and other novel features of materials at the nanoscale [33].

This makes the issue of environmental sustainability more important than it ever was. The brighter spot is that quite a lot of awareness is being created on environmental issues the world over. The world has realized that it is the high time that we resort to discriminate the use of natural resources and try for lower contamination. People and organizations are addressing pressing energy and environmental needs by deploying renewable energy sources, switching to energy efficient and less polluting ways of production, finding alternatives ensuring lesser need of raw materials for the same quantum of production, etc. Nanotechnology applications can reduce the environmental problems substantially with their targeted and indirect interventions. Nanotechnology has the potential to change the way the things are produced and processed and to further reduce their hazardous side and after effects. Environment developments in nano-bioprocessing can lead to conversion of agricultural waste into energy and other useful by-products, thereby transforming waste that can adversely impact the environment into valuable end-products [30]. Nanotechnology processes are used in converting waste fibers from cotton spinning into biodegradable cellulose mats that can absorb pesticides and fertilizers. Nanomaterials have also been used in the remediation of agricultural lands and groundwater contaminated by farm run-off. Photocatalysis using nanoparticles can be used to degrade pesticides and to treat wastewater [33]. Nanoscale iron particles can be used to catalyze the breakdown and oxidation of organic compounds such as tricholoethene, dioxins and PCBs in contaminated groundwater, after which the nanoparticles are degraded into a harmless form of naturally-occurring iron found in the soil [34]. Lanthanum nanoparticles that absorb phosphates in aqueous environments can be used for clean-up of ponds and lagoons; these may also have applications in preventing algae growth in commercial fish ponds [6].

Conclusion

Nano food innovations are still at very initial stage of research. We still lack the nano specific regulations. It is yet to be seen if organics and competing corporate interest will retard or redirect the development of nano food application. Until recently there were no national or international regulations to nano food particles, nor are there any specific internationally agreed protocols for assessing the toxicity or environmental impact of nanoparticles [35-36].

In early 2009 two significant moves changed the scenario. The Canadian government introduced the world first's nano specific regulations and called for mandated reporting on the use of nano materials .It was also proposed in European Parliament that food produced via nanotechnology should undergo risk assessment prior to approval, it also called for clear labeling of nano foods [37]. Like it has occurred with GM crops due to tighter regulation and consumer resistance in the north (developed countries) nano food could end up in the underdeveloped countries since research is still at very initial stage it could raise the issue of concern among consumers similar to GM foods [38].

Many scientists, government agency are joining civil society group calling for effective risk assessment procedures related to nano food products. Acceptance of nanotechnology will depend on large-scale research. There is still scope of research for formulating new policies the first and foremost criteria understanding the food processing at nanoscale. It is still at a very grass root level of research. Currently food products using nanotechnology is still very small. It does promise big and benefits for food safety, quality and shelf life. There is an opinion among scientists and researchers that nano materials are fundamentally different substances that can cause risk to human health and environment and thus need monitoring. Nanotechnology has the potential to improve food, making them healthier, tastier and more nutritious. Measures can be used to make packaging that keep the product inside pressure for longer time. This could also provide consumers with information on the state of the food inside.

Advances in nanotechnology offers challenges to government and industry, the food processing industry must ensure consumer confidence and acceptance of nano food. FDA and other regularly trade bodies should offer guidance and investment to the criteria to be followed in evaluating the safety of food, food packaging and supplemental and use of nano materials with novel properties. Bouwmeester., *et.al*. (2009) tabulated the different types of Nanoparticle (table 1) application in agro food production. [39].

Chain phase	Application	Nanotechnology	Function
Agricultural production	Nanosensors	Nanospray on food commodities	Binds and colors micro-organisms
		Hand-held devices	Detection of contaminants, mycotoxins and microorganism
	Pesticides	Nano-emulsions, encapsulates	Increased efficacy and water solubility
		Triggered release nano-encapsulates	Triggered (local) release
	Water purification/soil cleaning	Filters with nano-pores	Pathogen/contaminant removal
		NPs	Removal/catalysation/oxidation of contaminants
Production and processing of food	Food production	Nano-ceramic devices	Large reactive surface area
	Refrigerators, storage containers, food preparation equipment	Incorporated nano-sized particles, mostly silver, occasionally zinc-oxide	Anti-bacterial coating
Conservation	Food products	Nano-sized silver sprays	Anti-bacterial action
	Packaging materials	Incorporated sensors	Detection of food deterioration
			Monitoring storage conditions
		Incorporated NPs	Increasing barrier properties, strength of materials
		Incorporated active NPs	Oxygen scavenging, prevention of growth of pathogens
Functional food, consumption	Supplements/ additive	Colloidal metal NPs	Claimed enhanced desirable uptake of metal
		Delivery systems "Nano-clusters"	Protecting and (targeted) delivery of content
		Nano-sized/-clustered food/drinks (nutrients)	Claimed enhanced uptake

Table 1: *Applications of nanotechnology in the Agro food production sector.*

Nano foods are not the same thing as conventional food. It is very difficult to come to the general conclusion as to whether nanotechnology is good or bad for us. We don't have sufficient scientific exploration of whether naturally occurring nanosystems are beneficial to us or not however nanotechnology food packaging was assessed as less problematic. Mandatory testing of nano modified food is needed before they are allowed into the market. Standardized test procedure are needed to study the impact of nanoparticles in living cells as this will evaluate the potential hazards relating to human exposure to natural nanoparticles.

The potential of nanotechnology has been identified by many countries and many countries are investing significant amounts. The USDA has developed short term and long term plans to address challenges faced in the agricultural sector. More money has been allocated towards research and development for increasing and optimizing food colour, flavour and consistency.

In developing countries like Iran, they have developed their own nanotechnology program with a focus on agriculture. They have 35 laboratories with a focus on agricultural research. In India 22.6 million USD in 2006 budget has been allocated to Punjab Agricultural University in recognition of their contribution to green Revolution.

However there is concern over using nanoparticles in food as has arisen in case of GM crops. A recent report from Institute of food science and technology in UK has stated that more safety data are needed before nanoparticles are introduced in food, since in current legislation it is not required to incorporate use of nanoparticles in food labels so consumers are more likely to be unaware of its use in food items. Many questions still remain unanswered regarding the extent to which the concerns raised by public and civil society groups will shape future trajectories of nano agri food industries. A number of models for public engagement have been proposed to give a platform for expressing concern associated with the development of nanotechnologies. Many of these models have been criticized both for limited extent to which diverse interest groups have been included in deliberative dialogue and also for gaps in process of deliberation and actual formation of policy and regulation related to nanotechnologies [40]. Limited public participation may cause consumers lack of trust as has happened in case of GM food resulting in global opposition to GM crops and hence boycotting GM crops [41].

The future of nanofood applications is uncertain so the organic agri food sector has excluded nanotechnologies. In 2008, the UK soil Association -the world's oldest organic certifier has prohibited the listing of products derived from nanotechnology due to unknown ecological and health risk associated with exposure to nano particles. Organic certifiers around the world like the biological farmers of Australia are also following this lead and it is possible that more general food standards will exclude nano products and processes [42]. Due to sensitivity to consumer opposition and the potential loss of the market share, supermarkets in near future might also exclude/restrict nano food and nano based products, for e.g. German supermarket chain Metro has already responded to consumer opposition by recalling consumer loyalty cards that utilized nano-based identification tags [43].

Public and industry are concerned about controlling nanotechnology, managing the risks and considering potential gaps in regulation. Workers in industry and students in academic labs are the ones exposed to nano particles right now especially in developing countries where infra structure and training for health and environmental safety are lacking. Regulatory guidance is particularly important for small business which does not have the resource to devote to environmental health and safety. With growing number of nano based products out on the market, the federal oversight process will increasingly have trouble keeping up with the pace of product development and market entry as it will take several years to fund and conduct research on the health and environmental risks and even longer to amend or formulate regulations (The nanotechnology – Biology Interface: Exploiting models for oversight. Hubert H. Humphrey Institute of Public Affairs (University of Minnesota). September 15, 2005, Workshop Report).

The health and environmental impacts of nanoparticles and nanomaterials should be assessed. Environmental application of nanotechnology include improved monitoring& detection capabilities, ultra green manufacturing and chemical processing, waste minimization, reduced energy usage, clean energy sources, remediation and treatment technologies and sustainability applications. Implications research for nano materials include studies on toxicity and its mechanism, effect of manufacturing on ecosystem, transportation & fate of nano materials bio accumulation, transformation, availability & dose response assessment. If these issues are taken care of Nano technologic intervention in farming has bright prospect for improving the efficiency of nutrient use through nano formulation of fertilizer, surveillance and control of pest and diseases, development of new generation of pesticides and their carriers [44-45].

Nanomaterials can be used to penetrate & remediate subsurface areas but this could also lead to damage to ecosystem. EPA governs nanotechnology so as to protect the environment. Right now the promise of nanotechnology is still much undetermined so developers need to be very careful about what the promise nanotechnology can do. This can lead to adverse public reaction. The corporate science sector is investing heavily in nano agri food research and development, but many scientists and Government agencies are calling for effective risk assessments related to nano food products. The opposition encountered from organic sector plays a vital role in shaping the pathway of this technology. Many questions still remain regarding the concerns raised by the civil society groups and the consumers and it will no doubt have effect in shaping up future trajectory of the nano agri-food industries.

Nanotechnology is also an important part of precision farming. These days the trend is towards identifying the cause of problem and take action accordingly to the site affected with the problem instead of spraying the whole field thus also reducing and minimizing the use of pesticides and fertilizers. Networks of wireless nanosensors are scattered in the field. They provide detailed data on crop and soil conditions and thus do the job of crop scouting as well. Sensors with nanoscale sensitivity will be particularly important in realizing this vision [46]. Opportunities for applying nanotechnologies in agriculture lies in improving the plant genetically. Nano array based technologies for gene expression in plants that will overcome stress. Sensors and protocols are developed for its application in precision farming [47-48]. Nanofertilizers emerging as an alternative to conventional fertilizers can eliminate contamination of drinking water [23, 24]. The role of nanotechnology in improving the livelihood among the poor in third world nations is unanimously recognized [49].The number of International and US patents is increasing for all types of nanotechnologies worldwide [50].

The editors of nature estimated that any technology takes some 20 years to emerge from lab to be commercialized [51]. It might take a few decades to move from lab to land. Sufficient funding, appropriate understanding on part of policy makers and science administrators is needed for nanotechnology to be an integral and important part of agriculture.

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Volume 2 Issue 4 November 2015