Applications of NanoSensor in Food Industry and Agriculture

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Abstract— Food plays a vital role in human life as food features a nice influence on human health therefore food safety is incredibly important part in food industry and agriculture. There are several food contamination incidents (such as Australian strawberry contamination in 2018 and Taiwan food scandal in 2013,2014) and additional incidents like has driven countries to develop fast, sensitive and reliable ways to sight the food hazard as food has many artificial food additives and chemical residues. Nanosensors features a nice advantage to sight food parts in fast manner therefore nanosensor is an alternative which might be utilized in fast development. Linking nanosensors with trendy Information and Communication Technologies (ICTs) permits novel and online ways for various parts detection accompanied with high accuracy. There are many sorts of nanosensors which are developed to fulfil the various necessities of food examination (carbon nanotubes based electrochemical sensors for detection of cations, microbial cells and toxins, anions and organic compounds in food, nanosensors for detection of external and internal conditions in food packaging, various aptameters for detection of pesticides, antibiotics, heavy metals). The paper reviews development and application of the foremost Nano sensors in agriculture and food industry.

Keywords: Nanotechnology, Nanosensors, Agriculture, Food, Food Industry

I. INTRODUCTION

Food safety is a first and foremost concern of human life. As the food is globalizing rapidly there is a huge importance of food quality evaluation in all steps of agri-food supply chain. The supply chain includes all steps "from the farm to the table" production, distribution, processing, and marketing of agricultural food products to the final consumers (Fig. 1).

Globalization of food production at the side of client issues associated with food quality and safety have resulted in interconnected and world systems for the assembly and distribution of food, followed by important increase in food standards[1]. This approach needed a move from the previous end-of-line product scrutiny approach to a brand new surroundings during which quality assurance is needed at each step of food production chain to make sure safe food and to point out compliance with restrictive and client needs. As a result, coming quality and food safety assessment procedures would require extra essential components like low detection limits, high sensitivity and specificity, shrinking of instrumentation for moveable use, easy sample preparation steps[2].

The food and beverage sector may be a global multi trillion dollar industry[3]. A recent estimate of the worldwide economical impact of nanotechnology is projected to be a minimum of $3 trillion by 2020, which may employee 6 million labors within the rising nanotechnology industries worldwide[4]. This is often very attractive and has driven various food enterprises involved in development and marketing of novel nanomaterial based products, and improving production efficiency, food characteristics, taste and safety. Incredibly, there are many products that have already been marketed and utilized in the food business over the past decade. Majority of those products are designed "out-of-food" but "inside" food industry, i.e. food contacting materials but indirectly consumed by people. No novel nanomaterials containing products are directly put into human food yet, except titanium oxide and iron oxide that are used as food pigment and colorant respectively already. The elemental reason is that regulation and legislation is extremely limited regarding nano food, especially thanks to complexity of nanomaterials and case-bycase legislating procedures[5-7].

Unfortunately, several of the nanotechnological tools for food and agriculture field ar still on a groundwork level. Solely sensible applications of engineering science ar in food packaging and in nanosensors for detection of food contaminants. Engineering science, nanominerals and nanosensors within the agri-food sector, as well as feed and nutrient parts, intelligent packaging and quick-detection systems, will be seen as new supply of key enhancements within the rural sector (Fig. 2). Innovative enhancements for the molecular treatment of diseases, fast sickness detection, victorious addressing viruses and crop pathogens, enhancing the facility of plants to soak up nutrients also as lowering usage doses of pesticides and herbicides proven that engineering science has the potential to revolutionize the agricultural and food trade[8]. To grasp and address the importance of engineering science within the agri-food sector, this paper represents a review of sorts and applications of the foremost gift nanosensors in agriculture and food trade. Even there's a belief that engineering science also will defend the setting indirectly through the employment of renewable energy provides, and filters or catalysts to scale back pollution and clean-up existing pollutants[8], there ar still several considerations concerning nanomaterials toxicity.

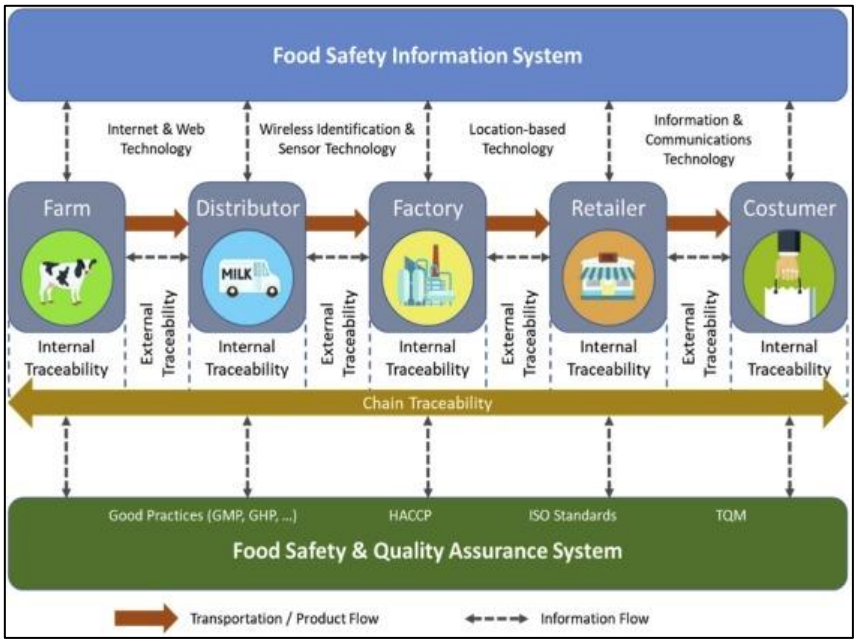

Fig. 1: Agri-Food Supply Chain

And doable negative impact on the environment. Aboard the potential blessings of engineering science applications within the agri-food offer chain, considerations concerning nanotoxicology and safety are mentioned also.

II. Development of Nanosensors in Agri-Food Sector and Their Applications

Nanosensors have the arrangement like normal sensors, however their production is at the nanoscale. Therefore, nanosensor will be outlined as a very tiny device than will bind to no matter is needed to be detected and challenge a symbol.

These small sensors area unit capable of police work and responding to chemical science (sensors) and biological aspects (biosensors), transferring that response into a symbol or output which will be employed by humans. Compared with ancient sensors and their shortcomings, nanosensors have many advantageous properties, like high sensitivity and property, close to period of time detection, low value and movableness and alternative necessary attributes that area unit improved by exploitation nanomaterials in their construction[9]. There are a unit several techniques for development of nanosensors that involves top-down lithography, molecular self-assembly and bottom-up assembly approaches.

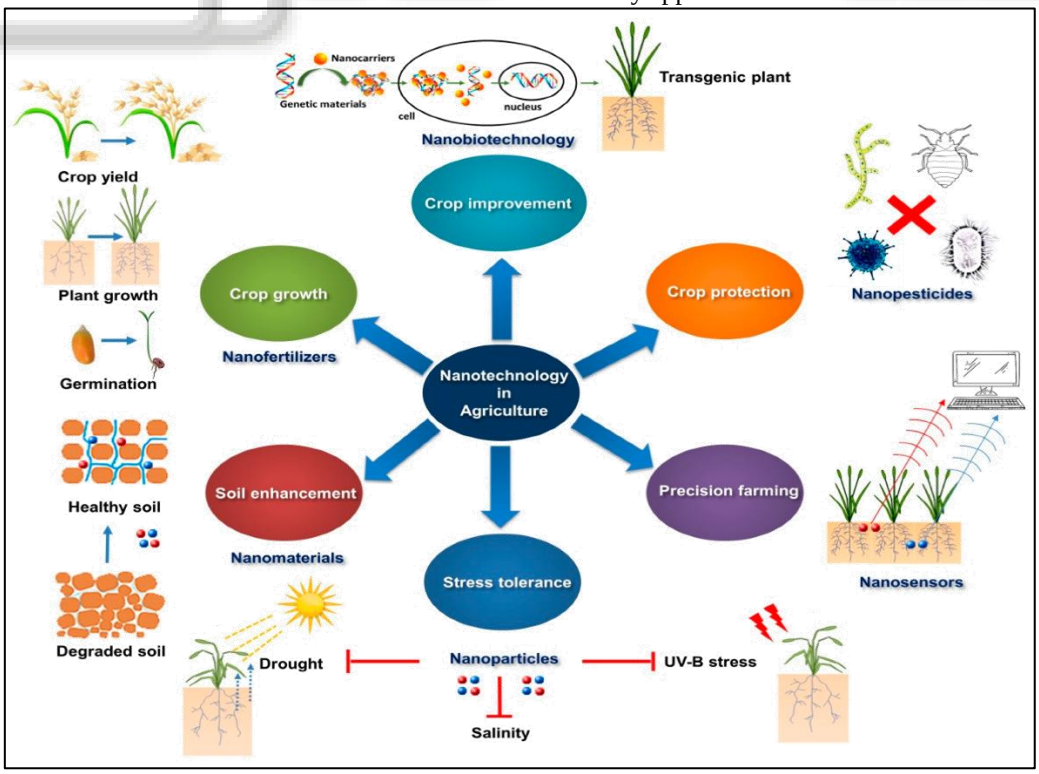

Fig. 2: Nanotechnology in Agriculture

Current nanosensors devices will be divided into:

- Nanowire nanosensors,
- Nanoprobes,
- Nanoparticles,
- Nanostructured materials - e.g. porous semiconductor,
- Nanosystems: cantilevers, Nano-electromechanical systems (NEMS).

Numerous nanosensors area unit developed for numerous applications in agricultural and food trade either to quickly determine threats within the case of suspected illness, or integrated into packaging as nanotracers to indicate the history of the nutrient and whether or not it's of acceptable quality at any given time. for example, the employment of nanosensors in food packaging to observe growth of microorganisms and alter color once a strength is reached, moreover as nanosensors applied in on-line method management, for observation of storage conditions area unit helpful for preventing illness[10]. The nanosensors utilized in food analyses use a mix of biology, chemistry and engineering science and should even be referred to as nanobiosensors.

As another example, scientists area unit creating the gold nanoparticles and coat them with molecules which will bind to substances like pesticides. Farmers might spray these nanoparticles on their fields to observe a chemical sort of a chemical[11]. It's necessary to say nanoparticle-based aptasensors consisted of aptamers (the target-recognition element) and nanomaterial (the signal transducers and/or signal enhancers). Aptamers area unit single stranded macromolecule or amide molecules of size but twenty five kDa with natural or artificial origin. They're extremely specific and selective towards their target compound (ions, proteins, toxins, microbes, viruses) because of their precise and well outlined three-dimensional structures. Aptamers area unit named as artificial ANtibodies because of their choice and generation through an in vitro combinatorial molecular technique referred to as SELEX. Dissociation constants of aptamers area unit in nanomolar or picomolar vary. Aptamers area unit extensively used as recognition parts within the fabrication of aptasensors[1]. There square measure a large kind of nanomaterials, which may be utilized in aptasensors (metal nanoparticles and nanoclusters, semiconductor nanoparticles, carbon nanoparticles, magnetic nanoparticles etc)[1].

 **Agriculture**	 **Food Processing**	 **Food Packaging**	 **Supplements**
• Single-molecule detection to determine enzyme/substrate interactions • Nanocapsules for delivery of pesticides, fertilizers and other agrichemicals more efficiently • Delivery of growth hormones in a controlled fashion • Nanosensors for monitoring soil conditions and crop growth • Nanochips for identity preservation and tracking • Nanosensors for detection of animal and plant pathogens • Nanocapsules to deliver vaccines • Nanoparticles to deliver DNA to plants (targeted genetic engineering)	• Nanocapsules to improve bioavailability of nutraceuticals in standard ingredients such as cooking oils • Nanoencapsulated flavor enhancers • Nanotubes and nanoparticles as gelation and viscosifying agents • Nanocapsule infusion of plant-based steroids to replace a meat's cholesterol content • Nanoparticles to selectively bind and remove chemicals or pathogens from food • Nanoemulsions and nanoparticles for better availability and dispersion of nutrients	• Antibodies attached to fluorescent nanoparticles to detect chemicals or foodborne pathogens • Biodegradable nanosensors for temperature, moisture and time monitoring • Nanoclays and nanofilms as barrier materials to prevent spoilage and prevent oxygen absorption • Electrochemical nanosensors to detect ethylene • Antimicrobial and antifungal surface coatings with nanoparticles (silver, magnesium, zinc) • Lighter, stronger and more heat-resistant films with silicate nanoparticles • Modified permeation behavior of foils	• Nanosize powders to increase absorption of nutrients • Cellulose nanocrystal composites as drug carriers • Nanoencapsulation of nutraceuticals for better absorption, better stability or targeted delivery • Nanocochleates (coiled nanoparticles) to deliver nutrients more efficiently to cells without affecting color or taste of food • Vitamin sprays dispersing active molecules into nanodroplets for better absorption

Table 1: Applications of Nanotechnology

Also, a large kind of transducing systems are utilized in aptasensors for food quality assessment and safety. The principles of aptasensors square measure supported the property of the nanoparticle getting used. Based on the detection systems, aptamers is classified into optical and chemistry systems. Furthermore, nanosensors using Raman spectrum analysis square measure ideally suited to food rhetorical. Food forensics is investigation of food origin, adulteration and contamination. Nanosensors application during this contributes to the specificity of the tactic and permits application of varied analytes which may be probed; starting from the macro-food, lipids, proteins and carbohydrates, to the minor elements, dyes, pigments, preservatives. More samples of nanosensors and their development for agriculture and food applications square measure delineated in[10][12][13], in line with Fig. two and performed surveys of analysis articles [8][14][9][15][16][17][18], the list of potential applications of nanosensors in agri-food offer chain is summarized, because it is shown in Table 1.

It is highlighted that nanosensors square measure helpful for sensing and coverage real time info concerning the merchandise from production through to delivery to the patron. Nanosensors square measure removed from being merely a passive, information-receiving device. They will get info from immediate and remote contexts and may analyze,

record and report knowledge. They will be designed to manage this at crucial management points within the offer chain-from the purpose food is created or packaged, through to the time it's consumed. The newest developments have resulted in nanosensors ability to supply quality assurance by following microbes, toxins and contaminants through the food process chain by victimisation knowledge capture for automatic management functions and documentation.

III. TOXICOLOGY AND SAFETY ASPECTS OF NANOSENSORS UTILIZATION IN AGRICULTURAL AND FOOD INDUSTRY

Despite the tremendous edges of nanosensors within the food business, there's an enormous public concern relating to toxicity and environmental result. There's terribly restricted data regarding its future adverse result on soil, plants and ultimately on human. Preliminary studies on animal have shown potential toxicity of nanomaterials for liver, kidneys, and system[19]. Therefore, risk assessment studies to indicate adverse effects of nanoparticles on human health ought to be standardized and their variety ought to be enlarged. Still, the actual fact is that direct exposure of customers to nanomaterials poses a heavy drawback to human health. As long because the nanoparticles stay certain, exposure is proscribed or terribly low. However, migration of nanoparticle incorporated in food material to human is high risk[16]. Health impact and safety relating to the appliance of nanomaterials was reported by Teow et. al (2011)[20].Trendy techniques unconcealed that nanomaterials with higher reactivity and talent to cross membrane barriers will result in totally different toxico-kinetic and toxico-dynamic properties. Some nanomaterials act with proteins and enzymes resulting in aerobic stress and generation of ROS that cause destruction of mitochondria and turn out cell death. Over the previous few years there are varied publications reportage a spread of biological and pharmacology interactions of nanomaterials in in vitro and in vivo experimental systems. a large vary of organic chemistry and pharmacology endpoints among every system are reported. Most are directed to pro-inflammatory and inflammatory markers since existing data on the health effects of close fine particulates and nanomaterials has known a central role for aerobic stress and inflammation within the pharmacology mode of action of nanoparticles. Therefore, the understanding of the biological and pharmacology effects of nanomaterials has considerably advanced within the previous few years. a lot of of this has been in relevance what style of physical characterization and pharmacology information is needed for hazard and risk assessment, and the way to travel regarding getting it. Serious adverse effects haven't been discovered in restricted applications to nanomaterials of 'traditional' tests for assessing the acute toxicity of chemicals. The pharmacology information sets on the market for nanomaterials stay rudimentary, as an example future inhalation studies, fruitful or biological process studies aren't on the market. The actual fact that, if nanoparticles area unit absorbed into the circulation, they'll be preserved among cells for long periods, makes it imperative that chronic studies be undertaken for hazard and risk assessment of nanomaterials.

IV. NANOSENSORS IN REALIZATION OF SMART AGRI-FOOD SECTOR

Inexpensive sensors, cloud computing and intelligent software system, hold the potential to rework the agri-food sector. web of Things (IoT), as Associate in Nursing rising reality wherever additional and additional devices square measure connected to users and different devices via the web, considerably contribute to the belief of the sensible agriculture by increasing the standard, quantity, property and value effectiveness of agricultural production. The innovative application of engineering in IoT creates a brand new paradigm, specifically the web of Nano Things (IoNT). Nanosensors, owing to their tiny dimensions, will collect data from varied completely different points. Nanosensors made up of non-biological materials, like carbon nanotubes, have ability to sense and signal, acting as wireless nanoantennas [21]. External devices will then integrate the info to mechanically generate implausibly elaborate report and answer probably devastating changes in their setting. For example, connected nanosensors for watching soil or plant conditions will alert mechanically in step with conditions detected by sensors and thus influence additional economical usage of the fertilizers, herbicide, pesticide, insect powder, etc. Involving nanosensors within the style of sensible or intelligent packaging, change the transfer of knowledge relating to product conditions throughout distribution or storage. The response generated thanks to changes associated with internal or external environmental issue, square measure recorded through specific sensors[16], hold on within the info and via web 24/7 out there insight into soil and crop health, food contaminations, quality, etc (Fig. 3). During this method, speedy response and reactions to detections of abnormally parameters' values, square measure enabled and cause additional quality and safe food, what direct influence to human health. However, to realize the total potential IoNT must provide in agriculture and food trade, several issues, relating to information security and privacy yet as nanomaterial's toxicity and impact to the setting and human should be thought of.

V. CONCLUSION

Recent advancements in applied science, embraced with intense analysis at each tutorial and industrial levels and advancements in ICTs, show its potential to absolutely influence the agri-food sector. Improved quality of the soil, accrued productivity, stimulation of plant growth, the utilization of precise farming, observation food quality and freshness throughout production, processing, distribution and storage, square measure just a few of the numerous advantages applied science, nanomaterials and nanosensors need to provide in agricultural and food business. The superb specificity of the nanosensors associate degreed aptamers permits an analysis of large choice analytes, as well as serious metal ions, toxins, pathogens, little molecules, nucleic acids and proteins. Nanoparticles add on to the property and convenience of the medical specialty, by the providing larger extent for aptamer immobilization similarly as by conferring their own opto-physical and chemistry properties to the detector. Some obstacles still exist within the development of field-applicable nanosensor techniques (sample pretreatment

technique, specificity, expenses). It is hoped that any insight into the probable solutions to those issues and within the development of novel nanomaterials can boost planning of cheap and simply operable nanomaterial primarily based sensing system. Therefore, the total potential of applied science within the agri-food sector is nevertheless to be realised. The long run researches are targeted within the development of novel reliable material, ways and good devices on the nano-scale, to the belief of IoNT vision, similarly on the analysis of their impact on the human and setting.

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