Integrative Food, Nutrition and Metabolism

Mini Review

ISSN: 2056-8339

The prospective role of nanobiotechnology in food and food packaging products

Charu Dwivedi[1,2], Ishan Pandey[3], Vatsala Misra[3], Michael Giulbudagian[4], Harald Jungnickel[4], Peter Laux[4], Andreas Luch[4], Pramod W Ramteke[1] and Ajay Vikram Singh[4,5*]

[1]Department of Biological Sciences, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad- 211007, India

[2]Nanotechnology Application Centre, Faculty of Science, University of Allahabad, Allahabad- 211002, India

[3]Department of Pathology, Motilal Nehru Medical College, Allahabad-211001, India

[4]Department of Chemical and Product Safety, German Federal Institute for Risk Assessment (BfR), Max-Dohrn-Strasse 8-10, 10589, Berlin, Germany

[5]Physical Intelligence Department, Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

Abstract

Nanomaterials have emerged over the past decade as promising commodities in many fields including cosmetics, environment, food and feed, healthcare, biomedical, optics, drug-gene delivery, health, mechanics and chemical industries. The food industry has also embraced the 'nano' era in response to a growing need by consumers for healthier and nutritionally appealing, cost effective products. The excellent future of 'nanotechnology' in the food industry has evoked food scientists to think innovatively to meet these demands. Applications of nanotechnology in food science are going to impact the vital aspects of food and related industries from food safety to the molecular synthesis of new food products and ingredients. Modern day nanosensors are being developed for improving food quality and safety and packaging techniques that will change the way food is stored and delivered.

Introduction

Nanotechnology is the systematic manipulation of matter on an atomic, molecular, and supramolecular spectrum. It also refers to the manipulation of atoms and molecules for the fabrication of the structures ranging in the macroscale dimensions [1]. This is nowadays more precisely called as molecular nanotechnology [2]. The National Nanotechnology Initiative (NNI) spells out nanotechnology as the scrutiny and utilization of entities traversing in dimension commencing 1 to 100 nm (http.//www.nano.gov). On the other hand, biotechnology utilizes the techniques and information of biology to manipulate the processes at molecular, genetic and cellular level to create novel products and services [3]. Nanotechnology is directed for food applications by two different approaches as "bottom up" and "top down"; which received enormous appreciation in preparing valuable consumer and therapeutic products [4-6]. Nanobiotechnology is a unique fusion of nanotechnology and biotechnology by which classical micro-technology can be merged to a molecular biological approach in real [7,8]. The top-down approach in the food industry is based on a physical processing of the food materials, such as grinding and milling [5,9]. The bottom-up approach in the food industry deals with building and growing of larger structures from atoms and molecules, for example, organization of casein micelles or starch and protein folding [4,6].

The eventual aspiration of nanotechnology echoes that of the requirements of food industry: errorless as well as prompt processing with cost effective ingredients deprived of any obnoxious property. Novel ingredient processing formats even agonize from plenty of flaws and are a matter of momentous confrontation following investigators and food scientists. For these exceptional virtues, the nanomaterials have been called as "wonders of modern medicine" [10,11]. Currently, only a few processing techniques can successfully produce nanofibrous scaffolds, on the nanoscale [11].

In the contemporary years, nanomaterials have secured ubiquitous contemplation of investors and investigators due to their comprehensive assortment of implementations in the domain of food industry. Nanomaterials are endowed with a number of noticeable virtues such as their dimension (10-100 nm), physicochemical and biological characteristics including shape, chemical composition, surface structure and charge and build variance lining up from nanoparticles, quantum dots, nanocrystals to carbon nanotubes/and nanofibers [10,12,13]. The clinicians have got prodigious liberty to pick a nanomaterial stationed on explicit implementation. Nanomaterials may set mechanical benefits and therapeutics concurrently by imbuing them in the company of antimicrobial virtues and filling materials. Nanomaterials display novel and improved properties due to their morphology, size and size-distribution over the bulk materials from which they are made [14]. They are appropriate to manufacture thin films, hold high surface to the volume ratio (S/V), diameter and pore size corresponding with natural tissue fibers; mechanical strength and light weight that avert compression of injured tissue *in situ*. Owing to the increase in the surface area, surface energy and catalytic reactivity of nanomaterials, their biological attributes and efficacy can increase proportionally [15].

***Correspondence to:** Ajay Vikram Singh, Physical Intelligence Department, Max Planck Institute for Intelligent Systems, Stuttgart, Heisenbergstr. 3, 70569 Stuttgart, Germany, Tel: 497116893439; Fax: 497116893412; E-mail: avsingh@is.mpg.de; Ajay-Vikram.Singh@bfr.bund.de

Received: November 07, 2018; **Accepted:** November 23, 2018; **Published:** November 26, 2018

Nanotechnology in contemplation with encapsulation techniques has provided numerous sophisticated techniques which enabled the design of devices to be used in the food industry. Such nanostructured devices could offer numerous benefits in various aspects of food science [16]. Food technology is regarded as one of the industry sectors where nanobiotechnology will play an important role in the future. It is commonly distinguished between two sectors of food industry applications: food additives (nano inside) and food packaging (nano outside) [17]. Nanotechnology may be brought into service as division of food science to produce robust nanofibers and controlled-release nanoparticles to produce microbe resistance ingredients for the food industry**.** Accordingly, nanomaterials can be worth considering in favor of food technology investigations and implementations. Functional bioactive ingredients have received much attention in recent years from the scientific community, consumers and food manufacturers. Potential functional bioactive ingredients are vitamins, probiotics, bioactive peptides, antioxidants, etc. [18].

More engineered nanomaterials (ENMs) are soon to invade our farms, in our grocery stores, and on our plates, due to the ability to manipulate on the nanoscale. Powder that makes doughnuts white may have, until recently, been the most well-known food containing manufactured nanoscale particles [19]. Scientists and researchers are constantly making efforts to fabricate innovative functional food systems. Nanotopology has been noted as key determinant for the design of innovative nanostructures in the food sector. Nanotechnology is being employed in the food industry mainly [20,21].

1) To ensure quality control and safety through the design of nanosensors and nanobiosensors
2) To create devices for the for targeted delivery of nutrients through nutrition nanotherapy
3) To develop systems for controlled release of nutrients, proteins, antioxidants, and flavors through nanoencapsulation (smart/intelligent systems)
4) To create nanoscale enzymatic reactor for development of new product and food fortification by omega3 fatty acid, haem, licopene, beta-caraton, phitosterols, DHA/EPA

Nanobiotechnology application in the different sector of food industry

Nanobiotechnology has become a promising area in food industry. Recent achievements have been made in various areas of food science, including foods and food packaging. Due to the availability of a broad combination of linkages between the food industry and nanotechnology are extending storage life, enhancing food security, improving flavour and nutrient delivery, allowing pathogen/toxin/pesticide detection, and serving functional foods [22]. Following are the thrust areas in the food industry where nanobiotechnology plays a vital role:

Food appearance and taste

A majority of bioactive compounds such as lipids, proteins, carbohydrates, and vitamins are sensitive to high acidic environment and enzyme activity of the stomach and duodenum. Nanoencapsulation techniques have been used broadly to improve the release of these compounds [16,23]. As compared to larger particles which generally release such encapsulated compounds more slowly and over longer time periods, nanoparticles provide promising means of improving the bioavailability of nutraceutical compounds due to their subcellular size leading to a higher drug bioavailability. Encapsulation of the bioactive compounds not only makes them resistive to adverse conditions but also allows them to assimilate readily in food products, which is quite hard to achieve in non-capsulated form due to low water-solubility of these bioactive compounds [16].

Preservation or shelf-life

Bioactive component frequently gets degraded in functional foods and eventually lead to their inactivation due to the hostile environment. Nanoencapsulation of these bioactive components extends the shelf-life of food products by slowing down the degradation processes or prevents degradation until the product is delivered at the target site [24]. Moreover, the nanocoatings on various edible food materials could provide a barrier to moisture and gas exchange and deliver colours, flavours, antioxidants, enzymes, and anti-browning agents and could also increase the shelf life of manufactured foods, even after the packaging is opened [25,26].

Food packaging

Food packaging materials enable the preserving of taste, color, flavor, texture, consistency and nutrients of foodstuffs. Such materials possess improved mechanical, barrier and antimicrobial properties [23]. The importance of food traceability and monitoring during the transport and storage lead to incorporation of new technologies with embedded nano-sensors into food packages to track environmental conditions throughout the supply chain. Polymer nano-composites (bionanocomposites) are hybrid nanostructured materials with improved mechanical, thermal and gas barrier properties. The use of bionanocomposites for food packaging is more environmentally friendly solution since it reduces the requirement to use plastics as packaging material. The packaging material can be made biodegradable with the introduction of inorganic particles, such as clay, into the biopolymer matrix and can also be controlled with surfactants that are used for the modification of layered silicate [26].

Electrospun nanofibres in food industry

The novel properties of nanomaterials open a new era for the food industry. A plethora of functional nanostructural materials can be used as building blocks to create novel structures and aid in the addition of potent functionalities into foods. These include: nanoliposomes, nanoemulsions, nanoparticles and nanofibers, has described several of these structures, their actual and potential uses in the food industry [27]. Nanofibers are excellent materials for the development of structural matrix for artificial foods and eco-friendly food packaging material. Recently, nanofibers are being fabricated from food-grade materials, hence, their use will likely increase in the nearby future. Due to the morphology of nanofibers fabricated by the electrospinning process, they are being proposed better than current technologies for the development of such nanostructured materials [17].

The nanofibres and novel structures are produced by electrospinning process from synthetic and natural polymers enabling their use in wide area of applications such as new food ingredients, food additives, novel packaging, food sensors, and additive encapsulations [28]. Electrospinning is of great interest in the food industry to encapsulate functional components. It also protects and enhances the survival of probiotic bacteria and bacteriocins during their passage through the upper GI tract and during food processing and storage. Electrospinning is of immense importance in the food industry due to the lack of severe conditions of temperature, pressure and chemicals required for sensitive compounds. Bifidobacterium strains were encapsulated using a protein (whey protein concentrate (WPC)) and a carbohydrate (pullulan) as encapsulation material. Compared to pullulan, using WPC resulted in higher protection ability as it effectively prolonged the survival of the cells even at high relative humidity [29].

Thus, unsurprisingly, electrospun nanofibers have served as a delivery platform that may further improve food preservation and prevent food spoilage. Additionally, thee nanofibres and novel structures produced by electrospinning find their use in wide area of applications such as new food ingredients, food additives, novel packaging, food sensors, and additive encapsulations. Nanofibres, especially those produced from natural polymers have potential applications in development of high-performance packaging for food, food coatings, flavour enhancement, additive encapsulation, and nutraceutical applications due to their biocompatibility and biodegradability

Introduction of functional bioactive ingredients: Value addition to food nanostructures

Incorporation of functional ingredients in functionally coated nanomaterials to drive the development of functional nanoscale material integrated food product is another area of major active interest in the food industry. Nanocomposite materials have also attracted much interest in food technology due to a number of key characteristics owing to their mechanical strength. The structures are generally composed of a polymeric material in combination with a nanoparticle filler of one or more variety. The polymer types that can be widely used to form nanocomposites are broad and this has led to a better understanding of the key structural elements in their design [30].

Antimicrobial systems

Antimicrobial food packaging systems help control the growth of pathogenic and spoilage microorganisms on food surfaces, where microbial growth predominates. Such systems are interesting, since materials in the nanoscale range have a higher surface-to-volume ratio when compared with their microscale counterparts [31]. Nanoscale materials have been investigated for antimicrobial activity as growth inhibitors, killing agents or antibiotic [32].

Vitamin systems

Vega –Lugo and Lim [33] prepared an active packaging of electrospun nanofiber made of soy protein or PLA fibers with allyl isothiocyanate, a natural antimicrobial compound [33]. The electrospun fibers could release the active compound though humidity triggering. Torres *et al.* [34] studied the protein/chitosan nanofibers with biocide [34].

Enzymatic systems

Enzyme entrapments in hollow fibers or microcapsules have been developed. In the enzyme immobilization method, the size of the carrier materials plays a key role. Greater size reduction results in higher efficiency of immobilized enzymes, due to the provision of higher enzyme loading per unit mass. Therefore, the use of the electrospinning method to produce nanofibers is considered an effective way to strengthen the functionality and the performance of enzymes. Dai *et al.* [35] evaluated the activity of encapsulated laccase in microfibers prepared from the poly (DL-lactide) (PDLLA)/PEO–PPO–PEO (F108) [35]. They found that up to 67% of free enzyme activity remained after the electrospinning process. Moreover, they reported that by encapsulation of enzymes in microfibers, laccase could be applied in a wider range of pH. Other studies also confirmed the feasibility of using emulsion electrospinning to incorporate lysozyme into polycaprolactone (PCL) and a blend of polyethylene oxide (PEO) and PCL. According to the obtained data, a smaller amount of lysozyme was released from PCL fibers, in comparison to PEO/PCL fibers [29].

Nanotechnology in monitoring quality change

Smart packaging materials could easily monitor the quality changes occurring during food storage. It shows great significance in the food industry. Boateng group added multiple pH dyes inside of fibers and these pH sensitive fibers were able to detect pH from a large range [36]. In another study, a fiber mat using pH-sensitive dye into was produced to monitor real-time pH change in food system [37].

Antioxidant systems

Nanofibers can provide mechanical reinforcement as a better protection for fragile textured foods and add other functional properties. Green tea has been extensively used to prepare edible food packaging materials due to antioxidant properties [38]. Bentayeb *et al.* have successfully designed food packaging films using oregano extract which exhibits antioxidant properties owing to the presence of rosmarinic acid [39].

Probiotic systems

Probiotics can be defined as living microbial supplements that can improve the balance of intestinal microorganisms. Krasaekoopt *et al.* [40] compared the survival of microencapsulated probiotics using different coating materials and found that chitosan coated alginate beads provided better protection for Lactobacillus acidophilus and Lactobacillus casei than did poly-L-lysine-coated alginate beads in 0.6% bile salts [40]. Moreover, chitosan-coated alginate beads provided the best protection for the strains L. acidophilus 547 and L. casei 01.

Colour additive systems

With the advent of nanotechnology, the use of a wide range of nanoscale colour additives is being and practised. Certain nanomaterial products have currently been approved for use as food colour additives, which have a vital role in the psychological appeal of consumer products. Colour additive mixtures for food use made with TiO_2 may also contain SiO_2 and/or Al_2O_3, as dispersing aids not more than 2% total. However, the use of carbon black as a food colour additive is no longer authorized [22].

Conclusion

A plethora of current developments have been made in the area of nanobiotechnology applied to the food industry. It embodies numerous aspects starting from food processing and packaging to food safety and quality control. The potential of nanobiotechnology has been witnessed in the development of functional food, nutritional supplements containing nano-food ingredients such as; antioxidants, vitamins, antimicrobials and colour additives. Such functional food containing nano-food ingredients enhances the taste, absorption and bioavailability. Recently, in silico methods are gaining popularity to elucidate the potential of proteins and peptides to me integrated into nanoscale novel materials, which could largely fit in different context food technology [41]. Naturally occurring nanobiosystems are least known to the food scientists and hence, there has been insufficient exploration of their existence and benefits. It is widely expected that nanotechnology- derived food products will be available increasingly to consumers worldwide in the coming years. Electrospun nanofibres are gaining widespread attention of food scientists as food packaging materials or encapsulating various food ingredients. Nanofibres may be included in structured polymeric films and they may aid in analytical devices as they provide high surface area and mass transfer rates and hence, makes them a suitable candidate for their use in pathogen detection in many areas. Advances in the research associated with food nanotechnology ingredients raises serious public concerns about their biosafety. Hence, a comprehensive risk assessment programme needs to be chalked out before the nanobiomaterials based food products are commercially available for human consumption and use. Development of algorithm and advances in Artificial Intelligence (AI), could be borrowed to material quality predictions for food safety make easier [42,43]. One of the major apprehensions for food scientists is the improvement in the safety and quality of food. While considering the variety of food nanostructures, the progress made in the area of food nanotechnology is confirmed. Extensive research is therefore needed to elucidate the differentiation potential of nanofibres in the area of food technology. Far into the future, new insights could be gained regarding the interactions of multiple food ingredients. Future developments could provide the technology to extend the scope of production of ingredients to the food industry.

References

1. Drexler KE (1991) Nanosystems: Molecular machinery, manufacturing, and computation. Univ.
2. Drexler KE (1992) Nanosystems. Molecular machinery, manufacturing and computation.
3. Tisato V, Zuliani G, Vigliano M, Longo G, Franchini E, et al. (2018) Gene-gene interactions among coding genes of iron-homeostasis proteins and APOE-alleles in cognitive impairment diseases. *PLoS One* 13: e0193867. [Crossref]
4. Singh AV, Ferri M, Tamplenizza M, Borghi F, Divitini G, et al. (2012) Bottom-up engineering of the surface roughness of nanostructured cubic zirconia to control cell adhesion. *Nanotechnology* 23: 475101. [Crossref]
5. Singh AV, Mehta KK (2016) Top-down versus bottom-up nanoengineering routes to design advanced oropharmacological products. *Curr Pharm Des* 22: 1534-1545. [Crossref]
6. Singh AV, Maheshwari S, Giovanni D, Naikmasur VG, Rai A, et al. (2010) Nanoengineering approaches to design advanced dental materials for clinical applications. *J Bionanoscience* 4: 53-65.
7. Singh AV (2013) Biotechnological applications of supersonic cluster beam-deposited nanostructured thin films: Bottom-up engineering to optimize cell–protein–surface interactions. *J Biomed Mater Res A* 101: 2994-3008. [Crossref]
8. Fakruddin M, Hossain Z, Afroz H (2012) Prospects and applications of nanobiotechnology: A medical perspective. *J Nanobiotechnology* 10: 31.
9. Rai M, Ribeiro C, Mattoso L, Duran N (2015) Nanotechnologies in food and agriculture. Springer.
10. Singh AV, Gemmati D, Kanase A, Pandey I, Misra V, et al. (2018) Nanobiomaterials for vascular biology and wound management: A review. *Veins and Lymphatics* 7.
11. Dwivedi C, Pandey I, Pandey H, Patil S, Mishra SB, et al. (2018) In vivo diabetic wound healing with nanofibrous scaffolds modified with gentamicin and recombinant human epidermal growth factor. *J Biomed Mater Res A* 106: 641-651. [Crossref]
12. Singh AV, Mehta KK, Worley K, Dordick JS, Kane RS, et al. (2014) Carbon nanotube-induced loss of multicellular chirality on micropatterned substrate is mediated by oxidative stress. *ACS Nano* 8: 2196-2205.
13. Abdel-Wahhab MA, Márquez F (2015) Nanomaterials in Biomedicine. *Soft Nanoscience Letters* 5.
14. Hassan S, Singh AV (2014) Biophysicochemical perspective of nanoparticle compatibility: a critically ignored parameter in nanomedicine. *J Nanosci Nanotechnol* 14: 402-414. [Crossref]
15. Abdel-Mohsen A, Hrdina R, Burgert L, Abdel-Rahman RM, Hašová M, et al. (2013) Antibacterial activity and cell viability of hyaluronan fiber with silver nanoparticles. *Carbohydr Polym* 92: 1177-1187. [Crossref]
16. Singh AV, Hosseinidoust Z, Park BW, Yasa O, Sitti M (2017b) Microemulsion-based soft bacteria-driven microswimmers for active cargo delivery. *ACS Nano* 11: 9759-9769.
17. Ravichandran R (2010) Nanotechnology applications in food and food processing: innovative green approaches, opportunities and uncertainties for global market. *International Journal of Green Nanotechnology: Physics and Chemistry* 1: 72-96.
18. Singh Av, Xiao Y, Wang S, Yu Y, David H, et al. (2018b) Peptide-Induced Biomineralization of Tin Oxide (SnO2) Nanoparticles for Antibacterial Applications. *J Nano Sci Nano Tech.*
19. Chen H, Truckenmüller R, Van Blitterswijk C, Moroni L (2013) Fabrication of nanofibrous scaffolds for tissue engineering applications. *Nanomaterials in Tissue Engineering*.
20. Rashidi L, Khosravi-Darani K (2011) The applications of nanotechnology in food industry. *Crit Rev Food Sci Nutr* 51: 723-730. [Crossref]
21. Singh AV, Gharat T, Batuwangala M, Park BW, Endlein T, et al. (2018) Three-dimensional patterning in biomedicine: Importance and applications in neuropharmacology. *J Biomed Mater Res B Appl Biomater* 106: 1369-1382. [Crossref]
22. He X, Hwang HM (2016) Nanotechnology in food science: functionality, applicability, and safety assessment. *J Food Drug Anal* 24: 671-681.
23. Singh AV, Jahnke T, Wang S, Xiao Y, Alapan Y, et al. (2018b) Anisotropic Gold Nanostructures: Optimization via In-Silico Modeling for Hyperthermia. *ACS Applied Nano Materials*.
24. Gidwani M, Singh AV (2014) Nanoparticle enabled drug delivery across the blood brain barrier: in vivo and in vitro models, opportunities and challenges. *Curr Pharm Biotechnol* 14: 1201-1212. [Crossref]
25. Uttara B, Singh AV, Zamboni P, Mahajan RT (2009) Oxidative stress and neurodegenerative diseases: A review of upstream and downstream antioxidant therapeutic options. *Curr Neuropharmacol* 7: 65-74. [Crossref]
26. Bratovčić A, Odobašić A, Ćatić S, Šestan I (2015) Application of polymer nanocomposite materials in food packaging. *Croatian J Food Sci Tech* 7: 86-94.
27. Bajpai VK, Kamle M, Shukla S, Mahato DK, Chandra P, et al. (2018) Prospects of using nanotechnology for food preservation, safety, and security. *J Food Drug Anal* 26: 1201-1214. [Crossref]
28. Lopes Da Silva JA (2012) 13-Functional nanofibers in food processing. In: Wei Q (ed.) Functional nanofibers and their applications, woodhead publishing.
29. Nikmaram N, Roohinejad S, Hashemi S, Koubaa M, Barba FJ, et al. (2017) Emulsion-based systems for fabrication of electrospun nanofibers: Food, pharmaceutical and biomedical applications. *RSC Advances* 7: 28951-28964.
30. Singh T, Shukla S, Kumar P, Wahla V, Bajpai VK (2017d) Application of nanotechnology in food science: perception and overview. *Front Microbiol* 8: 1501-1501. [Crossref]
31. Singh AV, Vyas V, Patil R, Sharma V, Scopelliti PE, et al. (2011) Quantitative characterization of the influence of the nanoscale morphology of nanostructured surfaces on bacterial adhesion and biofilm formation. *PLoS One* 6: e25029. [Crossref]
32. Singh AV, Baylan S, Park BW, Richter G, Sitti M (2017a) Hydrophobic pinning with copper nanowhiskers leads to bactericidal properties. *PLoS One* 12: e0175428. [Crossref]
33. Vega-Lugo AC, Lim LT (2009) Controlled release of allyl isothiocyanate using soy protein and poly (lactic acid) electrospun fibers. *Food Res Int* 42: 933-940.
34. Torres-Giner S, Ocio MJ, Lagaron JM (2009) Novel antimicrobial ultrathin structures of zein/chitosan blends obtained by electrospinning. *Carbohydr Polym* 77: 261-266.
35. Dai Y, Niu J, Liu J, Yin L, Xu J (2010) In situ encapsulation of laccase in microfibers by emulsion electrospinning: Preparation, characterization, and application. *Bioresour Technol* 101: 8942-8947. [Crossref]
36. Boateng JS, Matthews KH, Stevens HNE, Eccleston GM (2008) Wound healing dressings and drug delivery systems: A review. *J Pharm Sci* 97: 2892-2923.
37. Van Der Schueren L, Mollet T, Ceylan Ö, De Clerck K (2010) The development of polyamide 6.6 nanofibres with a pH-sensitive function by electrospinning. *Eur Polym J* 46: 2229-2239.
38. Siripatrawan U, Noipha S (2012) Active film from chitosan incorporating green tea extract for shelf life extension of pork sausages. *Food Hydrocolloids* 27: 102-108.
39. Bentayeb K, Vera P, Rubio C, Nerín C (2014) The additive properties of oxygen radical absorbance capacity (ORAC) assay: The case of essential oils. *Food Chem* 148: 204-208. [Crossref]

40. Krasaekoopt W, Bhandari B, Deeth HC (2006) Survival of probiotics encapsulated in chitosan-coated alginate beads in yoghurt from UHT-and conventionally treated milk during storage. *LWT-Food Sci Tech* 39: 177-183.

41. Singh AV, Jahnke T, Kishore V, Park BW, Batuwangala M, et al. (2018a) Cancer cells biomineralize ionic gold into nanoparticles-microplates via secreting defense proteins with specific gold-binding peptides. *Acta Biomaterialia* 71: 61-71. [Crossref]

42. Singh SP, Rathee N, Gupta H, Zamboni P, Singh AV (2017c) Contactless and hassle-free real-time heart rate measurement with facial video. *J Card Crit Care TSS* 1: 024-029.

43. Khare MSA, Zamboni P (2014) Prospect of brain-machine interface in motor disabilities: the future support for multiple sclerosis patient to improve quality of life. *Ann Med Health Sci Res* 4: 305-312. [Crossref]