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Potential Application of Nanotechnology Based Innovations in Meat Industry

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Abstract

The demand of technology and innovations is increased in meat industry due to consumer awareness, health concern, sustainable production and higher socio-economic status. Nanotechnology includes the application of particles/materials at the Nano scale. Nanotechnology is new and innovative field of meat industry that involves the manufacture, processing and preservation of meat and meat products by controlling shape and nano size of particles to improve image of meat industry. Some emerging applications of nanotechnology like biosensors, intelligent, active and smart food packaging system and nano encapsulation of bioactive compounds can be used in bacterial identification and monitoring of food quality in meat industry. Nanotechnology has great potential to make available an general idea of current as well as future aspects of nanotechnology in meat and meat bio processing industry.

Keywords: Nanotechnology; Bio nanocomposites; Antimicrobial packaging; Nanoencapsulation; Nanosensors.

Introduction

The need for superior technology is raised with the advancement in meat science and world's growing need and concern over meat as a potential food source. Technologies that can help us to cope up with the complexity in scientific and engineering challenges in meat and meat processing industries. The answer to which is the most abundantly potential source of technology, i.e. Nanotechnology. According to National Nanotechnology Initiative (Arlington, VA, USA) nanotechnology is "the understanding and control of matter at dimensions of roughly –100 nm, where unique phenomena enable novel applications".

Enormous challenges are facing by food and bioprocessing industry for developing and implementing systems which can produces high quality, safe food along with this feeds while also being efficient, environment friendly and sustainable as well (Manufacture, 2006)

To combat these complex challenges innovative and newer as well as socially acceptable technological tools and processes are required in the meat industry. Nanotechnology is the emerging answer to these challenges to thus meet up the demands of the growing world population, which will be possible with increase in the economic status of the developing countries which comprise of major population part as well as also because of its social acceptance being a scientific technology. The impact of nanotechnology at least $3 trillion

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across the global economy 2020, Subsequently nanotechnology industries all over the world needed at least 6 million workers to support them by the end of decade (Roco et al., 2010).

Product can be described on the basis nanotechnique only when following approaches have been used in the production system.

A. When several ingredients have been processed to form nanostructures e.g. Nanosized nutrients to enhance the bioavailability of nutrients and improve sensory properties of product.

B. Where nanosized or nanoencapsulated additives and supplements have been incorporated in a product.

C. If the packaging materials utilize nano-particles to improve their quality.

D. When nanotechnology based device have been used in the packaging and processing of a product e.g. Nanosensors.

Application of nanotechnology in meat industry

Alfaand Elneshwy (2010) used the nanotechnology-based carrier system using 30 nmmicelles by incorporating in many additives to increase the productionprocess, stabilize colour, improving taste in industrial sausage. Weiss et el. (2006) used a nanoscale edible coatingwhich can be used as a medium to deliver colours, flavours, antioxidants, enzymesas well as developing the coating as thin as 5nm wide, which could be used onmeat, meat-based products and cheese etc. Shefer and shefer (2003) also developed the encapsulated system which act as vehicle to delivers the nutrients like protein and antioxidants for specifically targeted nutritional and health benefits.

Yusop et al., (2012) incorporated the nanoparticle paprika oleoresin which enhances the quality of products, increases the effets of marination and the sensory attributes of the chicken breast fillets. Cubuku et al., (2007) made a glassy carbon paste electrode which was based on xanthin oxidasec (XOD) and gold nanoparticles for the chronoamperometic detection of hypoxanthine in tuna fish samples, where the Analytical characteristics were determined, but no LOD was reported. Fernandez et al. (2010) reported that detectable levels of silver ions which leached out in the meat exudates when nanoparticle based coating was used.

Mills and Hazafy (2009) and Duncan (2011) developed the nanotechnology based sensor which detected the biogenic amines which were produces in the spoilage of fish and meat.

Abdou et al. (2012) observe the effect of anitimicrobial activity of chitosan nanoparticle on the growth of microorganisms in fish fingers and found that chitosan edible coating showed decreased bacterial counts. Joe et al., (2012) made nanoemulsion by using sunflower oil for processing of Indo-pacific market staeks, they observed that microbial growth decreased uo tp 12 hr except for control, as well as shelf life increased up to 48 hr.

Brody et al. (2008) prepared Durethan, a meat-packaging product of Bayer, which was polyamied plastic film incorporated with clay nalparticles and it act as an oxygen, moisture and carbon dioxide barrier. Fernandez et al. (2010) stated that antimicrobial application of cellulose pads which contain silver nanoparticle which generated from silver ions in situ and they found lower microbial load in exudates of beef meat packed in modified atmosphere packaging.

Panea et al. (2013) Reported that Zinc oxide (ZnO) and silver (Ag) act as a potent antimicrobial when used in as a nanocomposite with Low density polyethylene and found that inhibition of pathogens like P. Aerugenosa and L. Monocytigenes by using of this type of pacjaging materialfor chicken breast.

Villamizar et al. (2008) developed a network of single walled carbon nanotubes for construction of a Field Effect transistor biosensor for Salmonella infantis Associated with the egg and especially the chicken meat industry and the device could detect at least 100 CFU ml^{-1} of the pathogen in 1 h.

Use of Nanotechnology in packaging

With increasing use of various technologies in the meat and meat processing industry, by using of nanotechnology biochemical and molecular pathways can be used directly to increased the shelf life whose qualities has been modified at molecular level. It gives a pathway to the future of food industry where something new and acceptable can be created which no other technologies offer.

The utmost motive of packaging is to ensure enhanced shelf life without spoilage and any alteration in the qualities of the product, i.e. Taste, aroma, appearance etc. Nanotechnolgy provides greater control in the packaging system, along with a guarantee of a superior shelf life product. Muscle foods are high in protein, perishable commodity, because of that they are ideal for nanotechnology assisted packaging.

As per Nanoposts Report (2008), nanotechnology based packaging may make uo to 19% in the share of nantechnological based products and its application in the global consumer goods industry.

Nanotechnology in the packaging industry can have following approaches (Chaudhry et al. 2008):

A. Incorporation of nanoparticles in the packaging materialto enhances the properties like flexibility, barrier, strength etc.
B. Active packaging; incorporation of nanoparticles having antimicrobial as well as oxygen scavenging properties.
C. Intelligent packaging; incorporation of nanoparticle devices like nanosensors.
D. Biodegradable polymer –nanomaterial composites.

Intelligent Packaging

Absence of recommended storage conditions may lead to products quality deterioration, and may further lead to generation of harmful toxins in the product which may even harm the health of the consumer. Some reports revealed that nanobiosensor for the detection of pathogens in the processing plants, altering the consumer, producers and distributors view on the safety of products (Chen et al. 2006; Helmke and Minerick, 2006). Nanosensors are ables to detection of specific pathogens and its metabolites which can inform the consumers about the products temperatures, light or O_2 exposures (tmpering) history, when these are integrated in packaging system (Cushen et al. 2012). Different detection devices have been developed to detection of various toxins, pathogens and chemicals in food packaging such as nanowires and antibodies (Dingman 2008). It not only helps in malcondition detection but also empowers the producer to auto check if there is any ill manhandling in the processing chain. Nanoparticles used as nanosensors are also able to detect the presence of gasses, aromas, chemical contaminants or respond to changes in environmental conditions (Azeredo 2009; Duncan 2011).

One of these methods is photo activated indicator ink for in-package oxygen detection which is based upon nanosized TiO_2 or SnO_2 particles and a methylene blue where the colour of the films varies according to O_2 exposure– it is bleached when there is no exposition and blue when film is exposed (Milan et al. 2013). Sensors may detect presence of some other gases such as gaseous amines, which are indicators of fish and meat spoilage, in very low concentrations (Mills and Hazafy, 2009; Duncan, 2011). Similar to gas sensors, the moisture sensors can denote the moisture level without destruction of the packaging of a product. This sensor allows quick and accurate determination of package moisture levels without invasive sampling; under the influence of humidity polymer-matrix of the packaging swells, which results in larger degrees of inter-nanoparticle separation and these changes cause sensor strips to reflect or absorb different colours of light (Duncan, 2011). Shan et al. (2009) developed calcium carbonate nanoparticles based xanthine amperometric sensor to determine the freshness of fish samples.

Bionanocomposites

Nanocomposite with biopolymers offer possibility for carbon-neutral biodegradable materials for packaging and create opportunities for developing countries to utilize their agricultural and forestry resources, by-products and wastes for development of biopolymer nanocomposites (Chaudhry and Castle, 2011). The use of nanoclays into a poly lactic acid biopolymer increases barrier properties to oxygen and water vapor and extends the shelf life of food products (Lagaron et al., 2005). Bionanocomposites use biodegradable materials and incorporate nanomaterial fillers to minimise the disadvantages of not using traditional packaging materials (Sorrentino et al., 2007). They not only extend the shelf life of with the aid of nanofillers, but nanocomposite also reduces the use of plastics as packaging materials and supports biodegradation and eco friendly methods of disposal of packaging materials (Sozer and Kokini 2009).

Green Packaging

Natural biopolymer bio-nanocomposites-based packaging materials have great potential for enhancing food quality, safety, and stability as an innovative packaging and processing technology. Plantic Technologies Ltd, Altona, Australia has manufactured and is selling biodegradable and fully compostable bioplastics packaging (CSIRO, 2006), made from organic corn starch using nanotechnology. Bio degradable bio-nanocomposites prepared from natural biopolymers such as starch and protein exhibited advantages as a food packaging material by providing enhanced organoleptic characteristics such as appearance, odor, and flavor (Zhao et al., 2008).

The unique advantages of the natural biopolymer packaging are that these can handle particulate foods, can act as carriers for functionally active substances and provide nutritional supplements (Rhim and Ng, 2007). Kriegel et al. (2009) have developed a methodology using electrospinning technique for making biodegradable green food packaging from chitin. Chitin is a natural polymer and a main component of lobster shells. The electrospinning technique involves dissolving chitin in a solvent and drawing it through a tiny hole with applied electricity to produce nanoslim fiber spins. These strong and naturally antimicrobial nanofibers were used for developing the green food packaging. Various companies like BASF, Ludwigshafen, Germany; New Ice, Durango, USA; Archer Daniels Midland CO, Decatur, USA; Sharp Interpack, Aylesham, UK and RPC Group, Northamptonshire, UK (BASF 2009; Bordes et al. 2009; Coating & Converting Magazine 2008) have produced food packaging bags and sachets from biodegradable polylactic acid and polycaprolactone obtained from polymer Nanocomposites of corn plant.

Nano encapsulation

Encapsulation may be defined as a process to entrap one substance (active agent) within another substance (wall material). The encapsulated substance, except active agent, can be called the core, fill, active, internal or payload phase. The substance that is encapsulating is often called the coating, membrane, shell, capsule, carrier material, external phase, or matrix. (Wandrey, 2009; Fang and Bhandari, 2010). Encapsulation is used to improve delivery of bioactive molecules (e.g. Antioxidants, minerals, vitamins, phytosterols, lutein, fatty acids, lycopene) and living cells (e.g. Probiotics) into foods (Wandrey, 2009, Vos, 2010]. Encapsulation provide barriers between sensitive bioactive materials and the environment and mask bad tasting or smelling, stabilize food ingredients or increase their bioavailability. Encapsulation also allow easier handling, (b) to help separate the components of the mixture that would otherwise react with one another, (c) to provide an adequate concentration and uniform dispersion of an active agent (Desai and Park, 2005).

Material used in encapsulation should be biodegradable, food grade, able to form barrier and “generally recognized as safe” (GRAS). The most important criteria for selection of an encapsulation material are functionality that encapsulate should provide to the final product, potential restrictions for the coating material, concentration of encapsulates, type of release, stability requirements and cost constrains(Wandrey, 2009). Most widely used for encapsulation material in food applications are polysaccharides Starch and their derivates – amylose, amylopectin, dextrins, maltodextrins, polydextrose, syrups and cellulose and their derivatives are commonly used. Plant exudates and extracts–gum Arabic, gum tragacanth, gum karaya, mesquite gum, galactomannans, pectins and soluble soybean polysaccharides are employed, too. Subsequently, marine extracts such as carrageenans and alginate are also present in foods. Common milk and whey proteins are caseins, gelatine and gluten. Among lipid materials suitable for food applications there are fatty acids and fatty alcohols, waxes (beeswax, carnauba wax, candellia wax), glycerides and phospholipids. In addition to the above, other materials are employed such as PVP, paraffin, shellac, inorganic materials (Wandrey, 2009).

Encapsulating compounds are very often in a liquid form, many technologies are based on drying. Different techniques like spray drying, spray-bed-drying, fluid-bed coating, spray-chilling, spray-cooling or melt injection are available to encapsulate active agents (Gibbs et al. 1999, Zuidam et al., 2009). Spray drying is the oldest and most extensively applied encapsulation technique in the food industry because it is flexible, continuous, but more importantiy an economical operation.

Effect on essential oil on shelf life

Antimicrobial compounds present in foods can extend shelf-life of unprocessed or processed foods by reducing microbial growth rate or viability (Beuchat and Golden, 1989). Essential (volatile) plant oils occur in edible, medicinal and herbal plants, which minimize questions regarding their safe use in food products. Compounds with phenolic groups are most effective (Deans et al., 1995; Dorman and Deans, 2000). The oils of clove, oregano, rosemary, thyme, sage and vanillin have been found to be most consistently effective against microorganisms. They Are generally more inhibitory against Gram-positive than against Gram negative bacteria (Zaika, 1988; Mangena and Muyima, 1999; Marino et al., 2001). Some which are effective against both groups (oregano, clove, cinnamon and citral; Kim et al., 1995a; Sivropoulou et al., 1996; Skandamis et al., 2002). Some non Phenolic constituents of oils which are more effective (allyl isothiocyanate, AIT; Ward et al., 1998) or quite effective against Gram-negative bacteria (garlic oil; Yin and Cheng, 2003). The oils with high levels of eugenol (allspice, clove bud and leaf, bay, and cinnamon leaf), cinnamamic aldehyde (cinnamon bark, cassia oil) and citral are usually strong antimicrobials (Lis-Balchin et al., 1998b; Davidson and Naidu 2000). Activity of sage and rosemary is due to borneol and other phenolics in the terpene fraction. The volatile terpenes carvacol, p-cymene, thymol, oregano, savory are responsible for the antimicrobial activity. Various spices like garlic, turmeric, ginger, mustard clove etc. show strong antimicrobial activity due to their active principles containing alecin, curcumin, gingibellin, isothiocyante respectively. Among herbs, basil, oregano, rosemary, sage and thyme also exhibit strin anitooxidant and antimicrobial activity and have been used in Indian culinary practices since time immemorial. Different phenolic components in natural essential oils are helpful to increased the shelf life of various meat products with their antimicrobial activity (Deans et al., 1995; Kim et al., 1995 a,b). Although, allyl isothiocyanates in mustard and allicin in garlic and onio are considered as non phenolic aliphatic compounds. Phenolic compound of olive oil (oleuropein) and tea-tree oil (terpenes), which are not classified as either herbs or spices, but show antimicrobial activity (Davidson and Naidu, 2000). Essential oils of plants have been shown to have activity Against Aeromonas hydrophila, Listeria Monocyto genes, Clostridium botulinum, Enterococcus faecalis, Staphylococcus spp., Micrococcus spp., Bacillus spp., Enterobacteriaceae, Campylobacter jejuni, Vibrio para haemolyticus, Pseudomonas fluorescens, Bacillus cereus, Shigella spp., Salmonella enterica, Typhimurium and Enteritidis, and Escherichia coli as well as yeasts and moulds (Saccharomyces cervisiae, Aspergillus Flavus Aspergillus parasiticus) (Karapinar and Aktug, 1987; Beuchat and Golden, 1989; Moleyar and Narasimham, 1992; Hao et al., 1998a, b; Smith-Palmer et al., 1998; Marino et al., 2001; Bagamboula et al., 2003).

Conclusion

Technological progress and revolutionary improvements with efficient economics in meat industry have led to innovation in the packaging line. meat and meat products need a specialized package profile depending upon the type of processing, condition of storage and distribution. New systems, materials, machinery, designs and environmental concerns are some innovations in packaging sector. Therefore, nanotechnology has a great significance on the meat processing industry, especially by extending shelf life of value added meat products along with development of functional meat products and novel packaging techniques. The potential benefits of nanotechnology can be utilized by improving bioavailability, antimicrobial effects as well as targeted delivery system of bioactive compound without any adverse effect on organoleptic properties of meat products.

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