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A REVIEW ON NOVEL USE OF NANOTECHNOLOGY IN FOOD AND DAIRY INDUSTRY TO ENHANCED FUNCTIONAL AND NUTRITIONAL QUALITIES

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ABSTRACT

The fast way food and dairy product are evolving is in relationship with use of novel nanoscale technologies. Food and dairy industries need sustainable technologies for food processing to produce products with flavorful, authentic fresh and suitable qualities in order to retain leadership of market for food and dairy products. Nanotechnology can be applied in the packaging of the food and dairy products or as additives to the food and dairy products. The food and dairy products packaged with nano-materials has shown to be more hygienic with health benefits. The use of nanoparticles as additives in food and dairy products makes microbial contamination difficult thus, increasing the products shelf-life. The nanoscale additives used to enhance food nutrition composition, texture, shelf-life and flavor may function as food indicator and/ or for detection of food pathogens. There is great scale of opportunities provided by the use of nanotechnology for improvement of new food products to enhance their functional and nutritional quality. The current examples of nanotechnology are Bioactives, nutraceuticals, pharmafoods and functional food. The use of nanoparticles as additives in food and dairy products is cost-effective compared to conventional additives in use.

Keywords: Dairy products; Food, Functional qualities, Nutritional qualities, Nanotechnology

INTRODUCTION

Currently, the dairy and food industries are in technological main transformation. There is instances of improvement than changes that occur dramatically in many products availability and choice of a consumer. The food commodities need by consumers is genuine, fresh and flavorful food products. To sustain leadership and get benefit in food and dairy

processing industry novel technology is required in the frontline. Nanotechnology have received attraction extensively in dairy and food industries among all novel technology in frontline, while both developing and developed countries have interest in empowering the technology more(Singh *et al*., 2017). The technology is on the scale of nanometer which deals with molecules, macromolecules and atoms with internal or surface structure in the range of 1-100nm (Hornyak *et al*., 2008).

Novel use of nanotechnology in food and dairy sector is the conjugation of nuclear and nanotechnology research to makes the delivery system of new nutrition matrices that carries the right active ingredients concentration to the right site of the human body and cells; Functional foods have gained the highest benefits from nanotechnology followed by nutra-ceuticals, standard food and others. Another novel use of nanotechnology is to enhance the status of nutrition in food and dairy products as reported by Boland (2014) and Joye *et al*. (2014). The death of more than half of children under five years old in developing nations occurs as a result of malnutrition. Many novel uses of nanotechnology and inexpensive agriculture have the prospective to decline mortality and malnutrition of infant. The food and dairy products are fortified with mineral, vitamin and other functional ingredients through nano-emulsion technology. In addition, carotenoids are being introduced as pro-vitamin A for the protection or prevention against serious human health disorders like heart disease, cancer and cataracts (Imran *et al*., 2010). For improved interest in the food nanotechnologies, there are other reasons like obesity is the payment of human kind for slow moving for computerization and motorization, and for these reasons, there is growing need for low fat contents food, though, that also affects their fat-soluble content of vitamins and other nutrients that is impacting their value of the nutrition (Popov *et al*., 2010). The novel use of nanotechnology enhances the functional and nutritional qualities of dairy products by improving its consistence like in yoghurt and ice cream (Coles and Frewer, 2013).

The food and dairy products color, stability, flow properties and shelf-life are enhanced by the nanoparticles added during the processing of the products. For instance, aluminosilicates are used as anticaking agents in powdered or granular foods whereas titanium dioxide anatase is a popular additive used in confectionery as food brightener and whitener, in sauces and cheeses (Alfadu and Elneshwy, 2010).

Novel Uses of Natural Nano Food

The essential component of food such as fat, carbohydrate and proteins are very beneficial in the manufacturing of nano-food through several methods (Morris and Parker, 2008). Recently, nano formulated foods show strikingly different sensory, functional and nutritional attribute that differ from conventional foods. The presence of native nanostructures in food could significantly enhance the functional performance of food (Shekhon, 2010). For instance, the crystalline structures in starch have effect on nutritional quality and gelatinization of processed starch-based foods can be controlled using nano technology (Rudolp, 2004). Denature constituents of milk protein is β-lactoglobulin developed by denaturing several factors like heat, pressure and drastic pH change are been compiled to framed larger gel-networks and the greatest proof is yoghurt (Momin *et al*., 2012). The α lactalbumin is also been used to grow nanotubes in hydrolyzation by bottom-up methodology (Bugusu *et al*., 2009). The homogenization processes and fine grating generate favorable atmosphere for synthesis of nano engineered products, while the reduced size of the fat globule is valuable for the synthesis of liposomes. The nano technical squall, fat globules, casein micelles and whey proteins are useful in dairy industry to formulate micro sized and nano sized structures to get required dairy products (Momin *et al*., 2012).

Nanotechnology Method

The top-down and bottom-up processes, are the industrially useful Nanotechnology methods employed in the processing of dairy and food products (Ravichandran, 2010). The top-down

involves translating materials of large size into nano-meter size range by using mechanical processes like milling, grinding, lithography and etching or by chemical degradation, using reduction or hydrolysis (Shibata, 2002). The bottom-up method nanotechnology was developed from the fundamentals of biological/chemical processes such as self – organization, positional and/or self- assembly of atoms through chemical synthesis or biological molecules (Sanguansri and Augustin, 2006).

Nano-emulsions Method

The emulsion of food is normally developed by application of functional food ingredients and processing method such as homogenization (Weiss *et al*., 2006), high pressure valve homogenizer or micro fluidizers can be used to produce nano-emulsion. Although, functional ingredient can be merged at interfacial region or continuous phase and droplet (McClements, 2004). The properties of texture and rheology of nano-emulsion is mostly due to droplet size that make them transparent and friendly to touch (Sommerville *et al*., 2000). According to the report of McClements and Dekker (2000) nano- structured multiple emulsions can present multiple encapsulating abilities from single delivery system due to properties that are complex. Nano-emulsion can carry many functional constituents and also release in response to a particular environmental trigger. Recently, it's possible to grow smart delivery systems by engineering the properties of the nanostructured shell around the droplets (Qureshi *et al*., 2012), that can aid the use of less fat without concession in creaminess for callery concern people and such notion is merged in manufacturing of ice cream by Unilever and Nestle (Renton, 2006).

Nano-Capsules Method

The casein performs as natural nano-capsules in nature for phosphates and calcium, which covers the constituent to supply neonates with important nutritive. The casein micelles have high biological activity with disparity to hold their basic structural identity in processing.

The casein micelle novel method of capsulation of hydrophobic molecules is for enrichment of low and high fat food products, which does not have any effect on sensory properties of the final food products. The major notion in the use of Nano-capsulation is to increase the absorption and control bioavailability of nutrients, vitamin, minerals and phytochemicals (Chavada *et al*., 2016).

Nano- Fibers Method

Nano-fiber developed from synthetic polymer by electrical spinning range from 10 to 1000nm in diameters are mostly, not from food grade biopolymers. Therefore, it has limited use in food industries. In future, it may be possible to manufacture nano-fibers from food grade biopolymers for use in food industries (Ravichandran, 2010). The nano-fibers are used as essential constituents of green food packaging for food matrices and to prevent against microbial attack.

Nano-Ceuticals Method

The word nano-ceuticals is form by two words which is pharmaceutical and nutrition, the nutra-ceuticals constituent show health benefits apart from nutrition quality, and, has potential to manufacture nano-ceuticals that contained equal properties (Chen *et al*., 2006), and the biological activity is increased by size reduction, improvement in delivery properties is noticeable and biological availability and solubility. Nutraceuticals can be calm during processing, utilization and storage, the notion of nano-ceuticals is increased acceptance of commercial food products and food supplements that contained nanoparticles are obtainable (Chen *et al*., 2006 and Mozafari *et al*., 2006). The food related nano-products for instance are carotenoids nanoparticles added to fruit drinks for better bioavailability, canola oil based nano-sized micellar system required to provide delivery of materials like minerals, vitamins or phytochemicals; Chinese nano-tea include nano-based mineral supplements that better selenium uptake.

Nano-Dispersions and Nano-Encapsulation Method

The Nanoparticles are important vehicle for delivery of functional components and their concentration required at exact site can be reached; examples are vitamins, drugs, antimicrobials, flavoring, antioxidants, preservatives and colorants. Some of the ingredients occasionally utilized directly in their pure form are included frequently into certain form of delivery system. The nano encapsulation and nano dispersion are perfect transport system because they comprise of bio polymeric nanoparticles, association colloids and nano emulsion (Weiss *et al*., 2006).

Association Colloids

The association colloids are particles uniformly scattered in nanometer size which is smaller than collide system particles. The examples of association colloids been used to delivered non polar, polar, amphiliphic functional ingredients and encapsulated includes bilayers, surfactant micelles, vesicles, liquid crytals and reverse micelles (Golding and Sein, 2004; Flanagan and Singh, 2006).

Table -1: Novel Nano-Foods and their Important/Uses

Nano-foods	Uses	Reference
i. Food Transformation	Nano-captors is used to detect contamination in food and quality of analysis.	Benn and Westerhoff, (2008)
	Nanostructured food is use to improved food color, taste, texture, flavor and consistency.	Chaudhry *et al*. (2008)
	Biocide surface like Silver nanoparticles and others are integrated into food for their antimicrobial properties.	Chaudhry *et al*. (2010)
ii. Food Nano packaging	Active nano-packaging of food use information systems where international substances are transfer between contents and packaging actively enhances the quality of product with prolonging shelf life of food. Maintaining organoleptic properties is two types like releasers and absorbers.	Smolander and Chaudhry (2010)
	It's used to enhance nano-packaging by improving mechanical and barrier properties.	Imran *et al*. (2010)
	Biocidal nano-packaging is use to prevent microbial growth allowed by presence of nanoparticles.	
	Biodegradable nano-packaging is use for packaging made from natural and polymers nanocomposites.	
iii. Consumption	Nano-ceuticals are used to increase absorption and bioavailability of health supplements, nutrients, active ingredients and nutra-ceuticals like cooking oil.	EPA (2011)
	Surface biocides is use to prevent microbial growth.	European Parliament (2012)
iv. Agriculture	Nanomedicine is use as new delivery systems for pharmaceutical substances for treatment of veterinary.	European Parliament (2012)
	Nano-filters use for treatment of wastewater, soil and agricultural waste.	ETC Group (2004)
		Joseph and Morrison (2006)

Packaging of Food with Nanotechnology

The packaging of food changes in answer to the science and technology material development as the consumer lifestyle is changing. In global economy today, food packaging is not only important for food preservation, but, also aids active delivery of the food products to the consumers, and to ease the end-use of product to communicate and convenience at the levels of consumer. The nano-packaging of food and dairy products keeps food product from internal and external hostile conditions through delivery and storage for instance, microorganisms, dust, water vapor, mechanical shock, vibrations and

gases. The occupied life style of the consumers in the modern society, motivated the producers of food and dairy products to develop packaging system that are functional to improve the product end use fitness. The packaging also give consumers important information about the product to ease the product advertisement and promotion. In the packaging systems that is higher, these functions are enhanced by mechanisms of communication which is motivated by process of chemical, biological and physical processes. The bright systems of packaging, are the ones that have improve function with reverence to marketing and communication functions like to give feedback that is active on the real quality of the product to the consumers. While on the other side the packaging that is dynamic focused on giving food preservation and protection by some activated mechanism with extrinsic and intrinsic factors (Lim, 2011). The powerful interdisciplinary tool for development of 47 novel products is known as Nanotechnology, and it's have been anticipated that at least $3trillion economic will be influenced globally through Nanotechnology in year 2020 which is creating a employers need of about 6 million in many industries (Ducan, 2011).

The food packaging related to nanotechnology globally in 2008 was about US $ 4.13 billion that projected to be annual growth rate of 12% (Packaging enable by Nano for Beverage and food industry, a global technology, market and industry analysis 2009). This trend globally in nanotechnology will give significant push to technology in dairy and food packaging industry to enlarge higher use of packaging to satisfy the consumers' desires. The nanotechnology is interdisciplinary linking the use of one or more dimensions of materials which is less than 100nm, Nano-materials normally can be grouped into three major classes such as platelets, fibers and particulates (Schmidt *et al*., 2002; Thostenson *et al*., 2005). Because of the dimensions of nano-sized, their materials have large surface to the ratio of volume and surface activity. The nano-materials can significantly improve the properties of material of the resulting nano-composites when been added to polymers that is compatible,

like improve thermal stability, enhanced mechanical strength and increased in the conductivity of electricity (Uskokovic, 2007). Although the nano-materials are encouraging to enhance the properties of the mechanical and barrier of food packages and also the growth of higher structures for sharp or intelligent and active uses.

Packaging enhanced: The nano-materials mixed into polymer matrix enhance the properties of gas barrier, temperature and humidity resistance of packaging. The active packaging shown by nano-materials use to relate with the food directly or the food environment to permit improved product protection. The silver coating and silver nanoparticles for instance, provides anti microbial properties with some materials used as UV or oxygen scavengers (Chaudhry *et al*., 2008; Kuorwel *et al*., 2015).

The sharp or intelligent packaging is devised for sensing changes due to microbial or biochemical reactions in food (Fortunati *et al*., 2013; Llorens *et al*., 2012), For instance, particular gases from food spoiling can be detected or particular pathogens developed in the food can also, be detected. Certain sharp packaging has been developed to be used as tracking device to avoid fake food products or for food safety.

Food and Dairy Products Packaging Using Novel Nanotechnology

The use of nanotechnology in food and dairy industries based on information collected worldwide is increasing and several food companies internationally are also, investigating prospective uses. Between the uses of nanotechnology for food and dairy sector, the nanotechnology derived food materials form which generate the major share of the recent - and short-term market anticipated. Many of -these products are available already in several countries, which is widely anticipated to be increasing in the next few years worldwide (Chaudhry *et al*., 2008).

Table 2: Packaging of Food Products Using Novel Nanotechnology

Nanotechnology in food packaging	Uses of Nanotechnology	Examples of Nanoparticles	Reference
Nanofilms	It possesses high antimicrobial activity. It help to protect fresh fruits like grapes. It acts as antibacterial agents.	TiO_2 based chitosan film. Ag based cellulose film.	Zhang *et al*., 2017 Gu *et al*., 2019
Nanosensor	They help in detecting any color change in food. They are also used in toxin detection like aflatoxin B1 in milk.	Gold and platinum based sensors.	Pradhan *et al*., 2015 Coles and Frewer, 2013
Nanocomposites	They act as oxygen scavengers. Use for coating of fruits, meats, bakery products and cheese.	Impermeable nanolaminate (nylon)	Thirumurugan *et al*., 2013 Flanagan *et al*., 2006

Recent Use of Novel Nanotechnology in Food and Dairy Industry

There is fast progress in food and dairy processing industries with use of nanotechnology. The main field used involved food texture alteration, sensation, taste development and encapsulation with improving the food nutrients bioavailability. Although, food packaging also, have been improved by use of nano-materials with antimicrobial and mechanical properties.

In food and dairy industry common plastic material used in packaging among several thermoplastics is polyolefin, the polypropylene films which are used frequently due to their brilliance, transparency, chemical inertness and low specific weight. However, polypropylene and other polymers is also characterized by low property barriers that

resulted in poor safety of packaged food. One major technique to reduce deficiency of other plastic barrier and polypropylene when it comes to packaging, is to add components like filler, multilayer or polymer blender according to Fabra *et al*., 2013; Han *et al*., 2011; NanosafePACK, 2012. The nano-composites of polymer base have been reported to have a better or the same barrier properties than their conventional counterparts of composite (Bott *et al*., 2014; Mihindukulasuriya and Lim, 2014), so such nano-composites can been strengthened with about 5wt% of nanoparticles due to their high aspect ratio (NansafePACK, 2012; Chaudhry *et al*., 2008). The nanoparticles are assimilated as supplement to additives and traditional fillers, but they have large ratios aspect when assimilated as fillers into walls of packaging and thus, improves gas barrier properties of the packaging material Hannon *et al*. (2015).

Other benefit derived from such materials are physical characteristics such as, durability, thermal stability and tensile properties (Beltran *et al*., 2014; Ducan, 2011), For instance, added UV-absorbers like, iron oxide, alumina, nano-titanium dioxide and silica to nano-composites to prevent the UV-degradation of titanium nitride (TiN) plastic polymers that are used to enhance the strength of packaging materials, nano-chitosan-polymer composites, nano-calcium carbonate polymer composites biodegradable cellulose nano-whiskers, other gas barrier coating like nano-silica and biodegradable nanoclay composites of starch and polylactic acid (Reig *et al.*, 2014).

Nano-clay is a renowned first nano-composites studied for use in the packaging of food to improve properties that have been assimilated with polyolefins, nylons, epoxy resins, polyurethane, polyethylene terephthalate and copolymers. Though beverage companies in some countries use certain materials already available commercially. The nano-composites preparations by mixing nano-silver with nano-clay or titanium dioxide to improve both antimicrobial and barrier properties have been studied for possible use in packaging of food (Cozmuta *et al*., 2014). Instances of other nano-materials possibly used in packaging of

food include polyhedral oligomericsilsesquioxane nano-clay to enhance barrier properties, polymer/silica hybrids to enhance oxygen diffusion barriers for plastics, nano-precipitated calcium carbonate to enhance mechanical properties, heat resistance and printing quality of polyethylene and zinc oxide calcium alginate nano-films used as food preservative(Bajpai *et al*., 2012).

Table 3: Recent application of Novel Nanotechnology in food and dairy products

Processing of Food	**Packaging of Food**	**Safety of food**
I. Nano-encapsulation: It improve the food flavor, aroma and also other food ingredients.	**i.** Active packaging: used of nanoparticles as antimicrobial agents in foods.	i. Detection of -pathogens: It is used against foodborne pathogens
ii. Nano-emulsions: It also improve dispersion and availability of nutrient in food.	ii. Smart packaging: Nano-biosensor and nano-coating for detection of pathogen in food.	ii. Detection of Toxins: To reduce heavy metals and chemical toxins.
iii. Neutra-ceuticals: They improve quality and nutritional value of food products.	iii. It improve packaging which include bio-based and ecofriendly edible packaging.	iii. Detection of Allergens: It's used as pesticide or anti-allergens.
iv. Nano-particles are used as viscosifying and gelatin agent to improve texture of food products.		iii. Inhibit Biofilms: It is used to stop biofilms on contact surface of food and food products.

Radha *et al*., 2014; Mohammed *et al*., 2022

CONCLUSION

The novel use of nanotechnology in processing and packaging of food and dairy products in industries is a vital tool in enhancing the nutritional and functional qualities, which will help to overcome existing challenges associated with processing and packaging materials. The improvement with nanotechnology will affect the food and dairy products safety, quality, security and shelf life positively in which both the producers and consumers will benefit. But, principle of protection should be practical and extra investigation is required, particularly on the behaviors of nano-materials immigration in food and dairy products with their possible effects on the safety or health and also, on the environment. The maintainable

processing and packaging solution with nano-materials can be reached, if only it is environmentally sound and economically possible

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