
I. INTRODUCTION

Food borne illness occur due to intoxicants and infections from food, which are obtained through consumption of contaminated food referred to as *food poisoning*. Most often, food borne pathogens are manifested with diarrhea and gastro-intestinal problems, which can vary based on severity and duration. The severity of the diarrheal and gastro-intestinal illness mainly depends on the infective dose of the pathogen. Diarrhea is a common illness, referred to as *global killer*. The global burden of infectious diarrhea involves 3 - 5 billion cases and nearly 1.8 million deaths annually, affecting the young children, caused by contaminated food and water. Diarrheal diseases account for 1 in 9 child deaths, worldwide. It is the second leading cause of death among children less than 5 years of age. In India, the diarrheal mortality rate is estimated to be 300,000 children each year (Bassani *et al.*, 2010).

The total diarrheal deaths was estimated to be 1, 58,209 among children under age 0–5 years. Proportionately, higher mortality rate was observed below 0–5 years age group of 9.1 per cent. Among Indian children, an average of 3.2 episodes of diarrhea /child/year. Even though, majority of diarrheal episodes are potentially fatal. The average incidence of diarrhea in children below the age of 0-5 year was 1.71 and 1.09 episodes/ person/year in rural and urban areas of India (NCMH, Government of India, 2005). India has made steady progress in reducing deaths in children among children below five years of age with total deaths declining from 2.5 million in 2001 to 1.5 million in 2012 (Bhan, 2013). Even though, diarrheal deaths have declined among children under five years, yet proportionately mortality rate still remains high.

The mode of transmission of diarrheal illness among children spreads by contaminated foods, poor personal hygiene, improper washing of utensils and poor sterilization of feeding bottles. The major etiological factors of diarrheal illness among under five children are the lack of hand-washing before feeding children and hand-washing without soap. Prolonged diarrheal illness may lead to complications such as malnutrition, growth retardation and immune impairment.

Among the varied etiological factors, food borne contamination poses higher incidence of diarrhea among the children below five years of age. Therefore, in India, food safety is becoming a challenging task to prevent microbial contamination of foods. The most common and dreadful species of diarrhea are the *enteropathogenic* species such as *E.coli*, *S.enterica* and *S.dysenteriae* respectively. These pathogens commonly spread through the unsafe food and water, which when stored in food packages like PET bottles, zip loc covers and infant feeding bottles, makes the food unfit for consumption and reduce shelf-life.

E.coli (*Escherichia coli*) is one of the most common and dreadful diarrheal species. It is a gram negative bacteria, which usually spreads through contaminated food stored in food packages affecting the digestive tract. *E.coli* infection is usually transmitted by contaminated foods such as raw milk where the bacteria spreads from the cow's udders to its milk. Raw fruits and vegetables like lettuce, alfalfa sprouts, unpasteurized apple cider and unpasteurized juices, comes in contact with infected water. The bacteria can also spread from one person to another, usually when an infected person does not wash his or her hands well after a bowel movement, *E. coli* can spread from an infected person's hands to foods. Globally, *E.coli* O157:H7 causes the most serious digestive tract infections all over the world. It spreads through eating of contaminated food, inadequate washing of feeding bottles and unpasteurized milk/ juices (RTE) beverages. Infection with *E.coli* O157:H7 strain causes the mild illness and bloody diarrhea. In chronic condition may cause the complication known as *Hemolytic Uremic Syndrome*, which leads to the breakdown of RBC and kidney failure.

Salmonella enterica are commonly known as *Salmonella choleraesuis*. *Salmonella* outbreaks due to non typhoidal *Salmonella* species are commonly seen in developing countries such as in India, where the mortality rate is as high as 24 per cent in developing world. *Salmonellosis* contributes to 20 per cent of childhood diarrheal illness with higher mortality among children (Chimalizeni *et al.*, 2010). The *Salmonella enterica* are the gram negative bacteria, which

usually spread through contaminated food, water and animals. *Salmonella enterica* are highly infested in digestive tract and are the common causes of diarrheal illness. Higher risk of *Salmonella enterica* infections are seen among processed packed foods like Ready to Eat (RTE) meat, poultry, milk and egg products. *Salmonella enterica* are highly infested in digestive tract through foods and are the common causes of diarrheal illness. These food borne infections of *Salmonella* produces gastroenteritis, bacteremia and enteric fever. The major food poisoning caused by *Salmonella enterica* is gastroenteritis, usually characterized by sudden nausea, vomiting, abdominal cramps, diarrhea, headache and chills. The symptoms can be mild to severe and may last upto 5 - 7 days.

Shigella dysenteriae is a gram negative bacterium which causes *Shigellosis* disease. It is also known as bacillary dysentery. *Shigella* is one of the most communicable and severe forms of the bacterial induced diarrheas. The global burden of *Shigellosis* has been estimated to be 165 million cases per year, out of which 163 million people affected by diarrhea are in developing countries. More than one million deaths occur in developing countries, yearly. *Shigella* is one of the most easily transmitted bacterial diarrheas through contaminated foods by fecal oral route. Handling toddlers' diapers, eating vegetables from a field contaminated with drinking water are the sources which can lead to *Shigellosis*. The infant feeding bottles with infected milk and water (*Shigella dysenteriae*) cause diarrheal diseases, especially among under fives. In children, *Shigella* easily spread through infected toys that children are likely to put in their mouth, which transmit the diarrheal illness. These pathogens commonly spread through contaminated food packages such as PET (Poly Ethylene Terephthalate), Ziploc covers (Poly Ethylene) and Infant feeding bottles (Polypropylene).

Indian food packaging is making a significant contribution to the economic development of the nation. The demand of Indian food packaging has been growing rapidly at 10% CAGR to reach 10 MnTPA by 2018. India observes a significant regional diversity in consumption of plastics with western India, accounting for 47 per cent, northern India for 23 per cent and southern India for

21 per cent. Therefore, increase in plastic potential in food processing, would help in meeting the needs of food and nutrition security of our nation. India's per capita plastics consumption was 9.7 kilograms in 2012-13 and is far below the 109 kg level in United States and 45 kg in China. The plastics industry of India is poised to increase the per capita income, rising consumerism and modernization, particularly in urban areas. The Plastic India Foundation estimated that polymer demand would increase to 16.5 MT by 2017-18 from 11 MT during 2012-13, with a rise by 10.8 percent of annual growth rate. India is expected to be among the top ten packaging consumers in the world by 2016 with demand set to reach \$24 billion. The food grade plastics used in food packaging comprises of Polyethylene terephthalate (PET), Polyethylene (PE) and Polypropylene (PP). These polymers exhibit superior mechanical and thermal properties in a wide range of conditions and are commonly used for specific purposes for storing the food items.

Plastic becomes a material of choice because of its sensational properties and low cost. Polyethylene Terephthalate (PET) is one of the major polymers worldwide contributes 18 per cent of world polymer production and holds the third ranking after Polyethylene and Polypropylene. It is estimated that the global consumption of PET packaging would grow to 19.1 MT by 2018. Globally, PET production was increased through transitional economies, in which the market has grown to 5.2 per cent per annum on India, Asia Pacific, South and Central America, Central and Eastern Europe, and the Middle East and Africa. The polymer consumption by Indian plastic industry is expected to reach 20 MT by 2020. The potential growth of PET is estimated to be 8 Kg in India, the annual per capita plastic consumption is as compared to 60 Kg in durables, juices, milk, teas, beer, and wine.

Zip lock covers are inexpensive flexible rectangular storage bags, usually used in developed nations. While plastic usage in India was primarily in household consumer mainly transparent, made of polyethylene. These covers are made of typically small size is 1.5 by 2.5 inches (3.8 cm × 6.4 cm) and a large size is 9 by 12 inches (23 cm × 30 cm). The material thickness (gauge) varies from 40 to 45 μm . The Zip lock covers (food grade) are most widely used for

storing variety of foodstuffs such as sandwiches and snacks. It is also used for storing foods at normal and freezing temperatures.

The global market trend shows that overall market of infant feeding bottles during 2009-2014 is \$2.47 billion. Among which India, shares five per cent of total global market of the feeding bottles. In India, infant feeding bottles are used by 60 per cent of parents either after birth or after breast feeding of four months. They are emerging as an important market across the globe. Infant feeding bottles are difficult to clean and sterilize frequently by working and non working mothers. Due to lack of food safety awareness and poor hygienic practices among mothers, contamination of bottles acts as a major source of diarrheal infections. At present, lifestyle changes, urbanization and ignorance of mothers (not reading the sterilization protocols) has led to the contamination of infant feeding bottles with high inocula of enteric pathogens. Often feeding bottles are highly contaminated with multiple enteric pathogens such as *S.dysenteriae*, that produce multiple outbreaks of diarrheal diseases among bottle fed infants. Undoubtedly, the safe use of sterilized bottles is a challenging task in developed countries.

In India, Epoxy resins and BPA (Bisphenol A) are solid organic compounds, which are used in larger proportion for the manufacture of polycarbonate plastics. BPA have been detected upto 46.05 ppm in the water used for sterilizing the baby bottles. In Indian feeding (PC) bottles, BPA migrates by about 19 ng/ml to hot water at 70°C. Owing to the continuous exposure of these chemicals via milk and solid foods, children are under high risk of altering the endocrine system, thus called as EDC (Endocrine Disrupting chemical). Thus, it is evident that endocrine disorders are on the rise among children, frequently encountered with thyroid disorder, early puberty, infertility and adenomyosis. Currently, as an alternate to overcome the health issues of Poly carbonate (PC) feeding bottles, they are replaced by Polypropylene (PP). However, to avoid food spoilages by preventing microbial growth in food packages, increasing shelf life and to prevent diarrheal diseases, an alternate technology is necessary. The application of nanotechnology, through nanocoating in food packages could act as an innovative approach to inhibit microbial growth in foods, extending shelf-

life, increasing barrier properties and improving food safety. Among the different noble metal nanoparticles, silver nanoparticles have gained boundless interest, because of their unique properties such as chemical stability, good conductivity and easily incorporated as coating and edible film onto the food packaging materials. Due to globalization, food packaging requires a longer shelf life to prevent microbial contamination of foods. Therefore, to address food safety issues, there is a need for nanocoated food packages which would improve the mechanical, barrier and antimicrobial properties of foods during storage.

According to World Health Organization (WHO) estimates, India potentially uses medicinal plant extracts for preventing illness, due to its eco-friendly nature, easy availability, low cost and minimal side-effects. In India, the medicinal plant trade is about US\$ 10 billion per annum with annual export of US\$1.1 billion. India has a rich heritage of medicinal plants of more than 8,000 medicinal plant species.

Silver nanoparticles synthesized from the chemical method leads to presence of toxic chemicals adsorbed on surface, which would pose adverse effect on food packages. Therefore, in search of environment benign (plant extract) commonly known as green synthesis. Due to its phytochemicals that are responsible for reduction of metal compounds into nanoparticle is sought in the present study. This green method is advantageous, because there is no need to use high energy, pressure, temperature and chemicals. Hence, in the present study, specific parts of medicinal plants were selected such as *Andrographis paniculata* (leaves), *Glycyrrhiza glabra* (root), *Curcuma longa* (rhizome) and *Leucas aspera* (leaves). The silver nanoparticles were synthesized using phytochemicals (plant extracts) which would increase the efficacy of antibacterial property in food packaging as a coating and as edible films. These nanoparticles possess larger surface area that are lethal to microbes, when exposed to it, thereby enhancing the antimicrobial property to food packages.

The present study aims to utilize nanoparticles from plants to improve the antimicrobial potentials, which would enhance the shelf life of foods. The silver nanoparticles have been permitted by FDA in direct food contact for plastic

packages. These nanoparticles incorporated onto food packages would help to absorb moisture from foods, thereby keeping the food fresh and prevent food spoilage. Besides, different polymers, starch is considered as most encouraging biodegradable material being low cost, broadly available and easily compostable without toxic residues. Hence, there is an uprising attention in the field of research by synthesizing bio-based polymers, loaded with silver nanoparticles, due to its potent low toxicity and inhibitory property. Therefore, as an alternate to synthetic polymers, we have tried out in the present study by synthesizing edible films from *Glycyrrhiza glabra* silver nanoparticles incorporated into starch as an edible film. These films would act as value added products are eco-friendly, safe to handle and cost-effective. In the light of these facts, the present study was designed by synthesizing nanoparticles from medicinal plants, which would improve the antimicrobial properties by reducing the surface contamination of foods in food packages with the following objectives :

1. Develop food containers with longer inhibition for diarrhea causing bacteria employing plants extracted with silver nanoparticles
2. Design food packaging containers for sustained sterility over longer duration using silver nanoparticles
3. Synthesise edible films (*Glycyrrhiza glabra*) silver nanoparticle, which could serve as value added products
4. Optimize Silver nanoparticles from four medicinal plants
5. Identify the Silver nano-coats using medicinal plants with highest antioxidant, antimicrobial and anticancer potentials
6. Coating of AgNP (*Glycyrrhiza glabra*) onto three food packages namely PET, Infant feeding bottles (PP) and Zip Loc covers (PE)
7. Develop food containers with longer inhibition against diarrhea causing bacteria by employing silver nano plant extracts

8. Develop food packaging containers using silver nanoparticles for sustained sterility over longer duration
9. Develop edible films of *Glycyrrhiza glabra* AgNP, which could serve as a value added products
10. Investigate the thermal, barrier and antimicrobial properties of Edible Films.