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Novel Methods in Food Packaging

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Abstract:- In recent years food packaging has come a long way and one can find numerous methods that have been under research to improve its functionality and efficiency. This paper studies the recent novel ideas and methods used for food packaging making a suitable road map for the average researcher including steps like material selection, manufacturing processes, design criteria's and added functionalities to the packaging system. Studies show that bio-plastics are more sustainable and have minimal carbon footprint and can be manufactured through foamed plastic process which is comparatively cheaper than the other processes and easier as well. They are very similar in structure to regular plastics giving them good mechanical properties and further coatings using layer by layer assembly or immobilization can give it an antimicrobial, antioxidant property as well. This is further explained in this paper.

Keywords:- *Packaging Materials, Functionality ,Manufacturing Processes, Carbon Footprint, Bio-Plastics.*

I. INTRODUCTION

Food manufacturing industry is one of the fastest growing industries in the modern day. This industry is growing globally and becoming very popular day by day. Most of the food that is supplied around the world is done through these industries, as they have the capacity and capability to do so. The food network is growing very rapidly and has shown a significantly higher percentage in growth as compared to any other business globally.

This calls for further research and development in the materials used for food packaging. Food packaging is also an essential part of this industry as there are various factors that come under consideration. Various foods require different packaging materials so that they do not spoil easily or develop a bad odour [11]. Some of the materials such as polymers, glass, bioplastics, paper, and metal foils are being widely used as they have certain characteristics that prevent the food from spoiling. There are various processes through which the characteristics of these materials can be further enhanced in order to improve their properties [13]. Hence, food packaging materials need to be given equal importance as they increase the shelf life of food, thereby, maintaining the quality of food.

II. MATERIALS AND METHODS

Each Material has its own characteristic property that makes it suitable for a particular style of packaging. The materials are as follows:

A. Glass

Glass is one of the most commonly used materials when it comes to food packaging industry, mainly due to its recyclability and neutral nature. It can preserve food for a longer duration (5-6 days) without any contamination (prevention of antimicrobial growth).[1]

B. Metals

Metals are proving to be optimal containers for food packaging materials. They are strong in nature, and are opaque, hence, not allowing any sunlight inside the container. Metals are coated with thin layers of aluminium, steel and tin to further enhance on their properties.[13]

C. Plastics

These are ideal materials that are being used for various applications, including food packaging. Plastics are pliable as well as cheap to manufacture, making it commercially viable for the companies to mass produce.[16]

D. Paper

Paper is a feasible option for food packaging, due to its high tensile strength and durability (Kraft paper). Although it is being used in various industries, the use of paper in food packaging is increasing exponentially.[5]

E. Wood

It is not a widely used material for food packaging, but it is mainly used as a means for bulk transportation of food.[12]

F. Bio-plastics

Bio-plastics are emerging as a potential material for food packaging as they can be great replacements for any fossil based plastic. They are sustainable and are normally manufactured from generic household/ industrial waste.[6]

All the above materials undergo various processes (heat treatment, pyrolysis) so that their properties can be improved, thereby, making them suitable for food packaging material [14]. Food packaging industries are finding economical and safer ways to produce various packaging materials that are hygienically prepared, eco-friendly and sustainable. The materials listed exhibit certain properties and are up to the standards (Food Safety and Standard authority of India- FSSAI) of the food packaging and manufacturing industries[3]. The table 1.1 below shows properties, composition of each material and various type of foods that can be stored in it. The food packaging industry is a fast-growing industry, and it relies heavily on the

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production of the packaging material [14]. So various designs and configurations of all materials need to be included, considering the functional criteria of the materials.

Material	Properties	Composition	Food Type
1)GLASS [15]	• Very rigid • Amorphous • High melting point • High Temperature • Null transparency • Becomes solid when cooled(at a certain temperature range)	• It has more of Silicon (around 60 to 75%) • For turning it from crystalline to amorphous it needs to heated in the range 1450 – 1500 degree Celsius • Low UV transmission (<150nm)	Juices, Soda and other Aerated drinks
2)METALS (a)Aluminium [16]	• Very expensive • Corrosion resistant • Higher thickness after anodisation (increases by 50 to 200 nm) • Malleable • Lightweight • Not fragile even at freezing temperatures • Higher thermal conductivity	• Around 8% (third element after silicon and oxygen)	Pulses, Rice, Grains
(b)Stainless Steel [17,18]	• High corrosion resistance • Economical • High resilience • Good thermal conductivity	• Chromium is the most common occurring material. Because of chromium the chemical inertness is more than 11%. • Austenitic type is used more for food packaging	Beers, Wines , Cokes
3)PLASTICS [12]	• Lower density • Amorphous • Non corrosive • Light weight • Flexible • Transparent • No oil penetration	• Around 75% is abundant • Most of the small scale industries use 35 to 40% plastic for food packaging	Fruits and Vegetables
(a) Low Density Poly Ethylene (LDPE) [18]	• Softer • Very flexible • Stretchable • Better clarity • It has a		Biscuits and Sweets

	comparatively lower melting point(110 degree Celsius)		
(b) High Density Poly Ethylene (HDPE) [17]	• It is a linear polymer • Higher crystallinity • It has a higher melting point (135 degree Celsius) • Greater tensile strength Better hardness		Butter, Vinegar, Milk
4)PAPER (Kraft Paper) [15]	• Relatively coarse • Stronger • High tensile strength • High tear resistance and elasticity Very durable	• Upto 31% is used for food packaging containment and its protection	Flour, Sugar, Dry fruits
5)WOOD [11]	• Largely porous i.e antibacterial • Capillary property to retain moisture • Strong durable	• Not very popular as a food packaging material as only 3 to 5% is used in the food packaging industry	Spices, Spreads, Meat
6)BIOPLASTICS [8,10]	• Flexible • Glossy • Transparent • Heat resistance • Printable • Eco friendly Less toxic to nature	• Around 7 to 9% is used for food packaging Lower carbon footprint (reduced use of fossil fuel resources)	Frozen Items

Table 1: Material Composition and Properties

III. MANUFACTURING PROCESSES

Processes	Material Used	Specifications	Types	Advantages	Cost
1.Extrusion [7]	Al,Plastic,Polymer	Extruder used • Operation • Construction	• Hot Extrusion • Cold Extrusion	• Better production • Uniformity • Flexibility	Low cost
2. Casting[7]	Thermoplastic materials	Material is melted and converted into flat	• Film can be stretched longitudinally and transversely	• Bio-oriented • Flexible • Stiffness and Toughness	Expensive
3.Extrusion Blow Moulding[7]	Resin,PET,HDPE, OPP, PS,PVC	Extruding parision into a mould equipped with the extrudor's die	• Injection • Injection Blow	• Easy to mould	Less expensive
4.Thermoforming [9]	ABS,HIPS,HDPE,OPP,PS,PET,PEI	Material is softened when it is heated and it is allowed to stretched	• Vacuum forming • Pressure	• Fast production • Economical	Moderately high

	G	into desired form	forming	savings	
5.Compression moulding[7	Polyster fibreglass resins system ,Torlon,Vespel,PPS,PEEK	Melted substance is compressed to get the desired shape	• Cold compression • Hot compression	• Simpler to use • Lower tool cost • Cost effective	Lower cost
6.Foamed plastics[8]	Foaming agent,Polystyrene, Polyethylene,Cellulose acetate		• Open-celled foam • Closed-celled foam	• Light weight • Good thermal insulation • Ease of moulding	Less material cost and Less production cost
7.Coating [7]	Paper,plastic or metal	Putting at least one layer of a liquid or melt substance to the surface of of a solid object	• Liquid coating • Extrusion coating	• Most extensively used • Flexible methods • Helps the environmental effects of plastic discharge	Reasonable cost
8.Metallization [7]	Oriented polypropylene & polyethylene, PET	Using heat evaporation to deposit a very thin coating of metal on a solid substrate		• Viable alternative for Al foils • Cost saving & down gauging	Cost saving
9.Painting [2]	Inks	Basically a decorative & instructive function	• Flexography • Gravure • Lithography • Screen printing • Ink jet printing	• It makes sure transmit marketing information • Catches consumer's attention	Cost effective

Table 2: Manufacturing Processes

IV. DESIGN CRITERIA

A. *Glass*

The major part is always chemical element (60to75%), unremarkably pictured as silicon oxide or oxide(SiO_2). Si material is that the most plentiful element on earth when oxygen, quartz, sand, cristobalite, and a variety of other minerals contain silica[5]. In minerals like feldspar and kaolinite, silicon is present as silicawhere silicon dioxide is linked to various metal oxides.The tetrahedron arranges itself symmetrically and continuously, with each oxygen atom connected to two silicon atoms, resulting in a well-ordered crystalline structure [13]. Silica exhibits clear polymorphism, being able to crystallise at different temperatures and resulting in a variety of forms available in various ores. SiO_2's crystalline state results in a very high melting temperature, a high toughness, little or no transparency, and poor inertness. When it comes to use and manufacturing, these characteristics are the polar opposite of what one would expect from a glass package [15]. In fact, the glass-making process converts inorganic ingredients from crystalline to amorphous via a primarily physical transformation that occurs at temperatures above 1,450–1,500 °C.[2]

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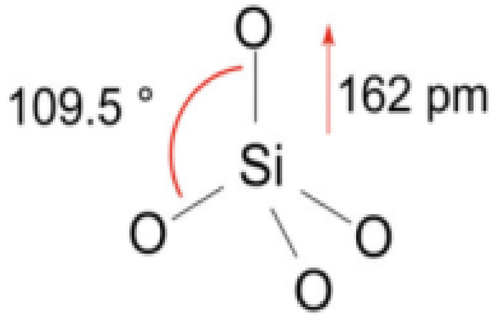

Fig. 1: The relation to crystalline form of silicon containing ores where each silicon atom is located at the centre of a tetrahedron having four oxygen atoms at the corner[10].

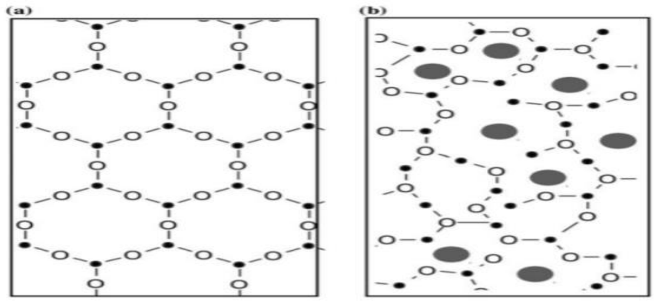

Fig. 2: The two-dimensional representation of the crystalline structure of a silicone containing ore and the amorphous one which includes atoms of sodium, calcium and magnesium in the empty spaces[1].

B. *Cellulose*

The majority of cellulose's chemical reactions are related to the cleavage of thee β-1,4 glycosidic bond and the possible reactivity of hydroxyl (OH) groups[14].The acidic hydrolysis of glycosidic linkages is much more effective on the amorphous parts of native cellulose, which are less dense.

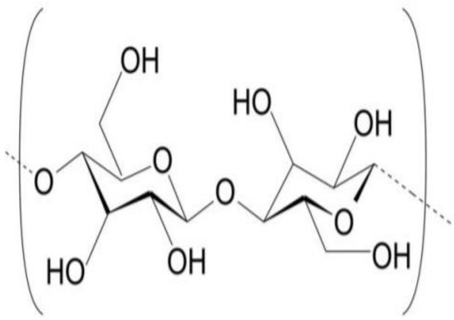

Fig. 3: The linear monomer of β-1,4- linked anhydro-D-glucose in the cellulose structure (cellobiose). has been used for drawing this structure[10].

C. *Polymer*

The most abundant (about 50 percent) polyethylene, to minor polymers that all together account for less than 2 percent of the total mass of plastics for food packaging purposes[17]. The basic formulas of discussed polymers are reported in Fig 4.4., while the meaning of all symbols used for plastic polymers used in packaging is reported together in Fig. 4.5 with related codes for recycling purposes[12].

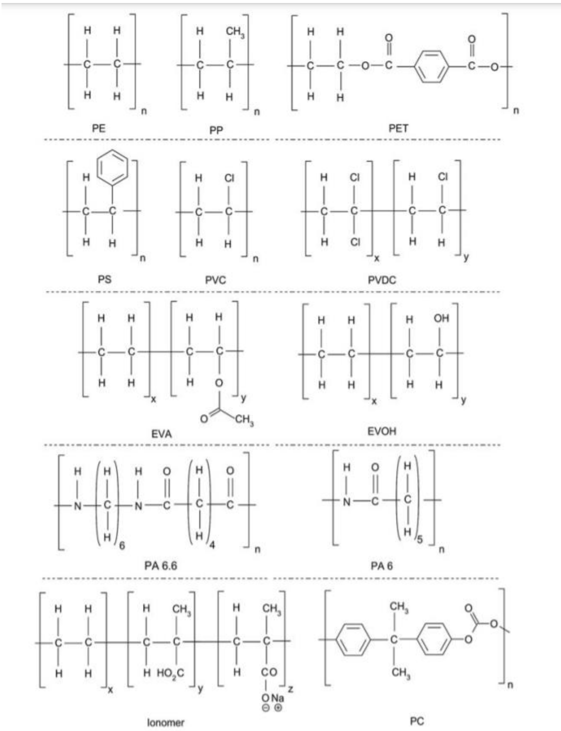

Fig. 4: The basic formulas of polymers commonly used in packaging applications: polyethylene(PE), polypropylene(PP) etc.[10]

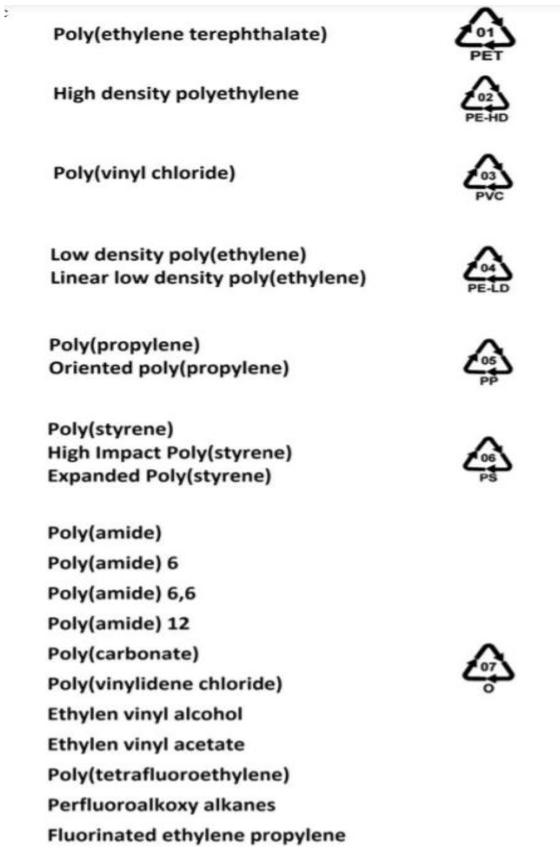

Fig. 5: Nomenclature and symbols used in food packaging systems [16].

V. FUNCTIONALITY OF NOVEL TECHNOLOGIES IN FOOD PACKAGING SYSTEM

Functionality refers to the different desirable advantages that the materials or processes involved possess. This makes it a very important factor in evaluating the overall impact of that specific method/product[12].

In recent years food packaging has come a long way in both research and implementation of the different ideas [3]. A comprehensive review in essence being a side by side comparison of these innovative and novel methods are important to a fellow student or to anyone attempting to work further under this field [2].

In terms of functionality, the parameters that would give a method/material an advantage over the rest would be its antimicrobial property, superior mechanical properties which all fall under active packaging[9]. This extra property apart from basic protection or basic containment is known as active packaging.

A. Active Packaging through coating technologies.

The different methods within coatings are namely, controlled release, immobilization, layer by layer assembly and photo-grafting [3].

a) Coatings using controlled release
In controlled release the matrices of the polymeric material have active agents integrated within them that diffuse to achieve the specific function[6] . Much of this method is used in laboratories and not so extensively in practical and commercial applications [2]. Temperature plays an important role in the case of controlled release as diffusion increases with temperature but so does the microorganisms therefore this type would be suitable for the antimicrobial function of the packaging system [7].

b) Surface Immobilization (covalent immobilization)
Surface immobilization deals with immobilizing an active layer onto the bulk material[11]. As polymer are generally inert it requires an initial functionalization. This works by forming an oxygenated reactive species on the surface like carbonyl (R-C=O), hydroxyl (R-OH) and carboxylic acid (R-COOH) groups [2]. Then the compounds of different functionality can be applied through covalent immobilization [18].

c) Layer by Layer assembly
This depends on the mutual attraction of polyelectrolytes. The deposition can be carried out by submerging the bulk material into a polyelectrolyte solution or by spraying the same onto the substrate [9] The deposition can improved by adjusting the pH of the solution being sprayed.

d) Photografting
This involves an extended exposure to UV light (315-400nm) in the presence of monomers and photoinitiators (benzophene $C_{13}H_{10}O$, thioxantone $C_{13}H_{8}OS$) which initiate the polymerization of the said monomers [2]. This can happen by electron transfer, hydrogen abstraction or through cleavage [4]. The active coatings are directly incorporated during the process or can also be done subsequently.

Coating Technology	Antimicrobial	Antioxidant	Biocatalytic
	Essential oils	Citrus oil	Lactase
Controlled release	Natamycin	Rosemary extract	Laccase
	Cinnamaldehyde		
	3-aminopropyltrimethoxysilane	Gallic Acid	Lactase
Immobilization[4]		Aluminium oxide	Catalase
	Lysozyme		
Layer by Layer	Lysozyme	Tannic acid	Lactase
Photografting	--	Caffeic acid	Trypsin
	--	Acrylic acid	Urease

Table 3: Photografting

B. Chitosan Used In Antimicrobial Films And Polymers

Chitin is one of the most abundant polysaccharides on earth ranking second after cellulose. It is found mainly in marine invertebrates like crabs, shrimps and other insects. From this chitosan is obtained by partial deacytylation [5].

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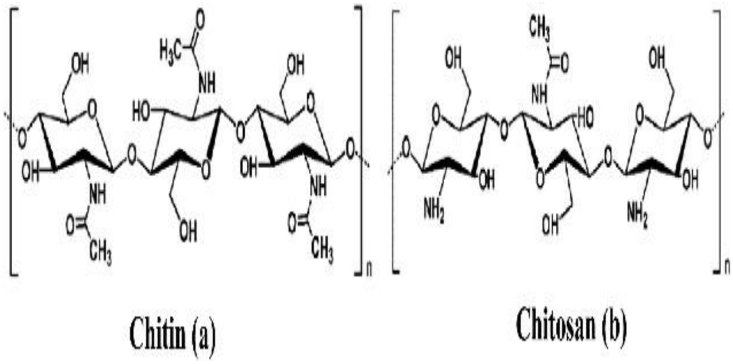

Fig. 6: Chemical structure of chitin and chitosan

Chitosan (low molecular weight, 20-300cP 1, deacetylation degree 75-85%) has good antimicrobial activity against microorganisms like Gram-positive and Gram-negative bacteria [5]. Films can be prepared with another compound, carboxymethyl cellulose sodium salt (CMC). The ratio of chitosan to CMC for the film is 1:2 [11]. The film manufactured was tested on bread and it showed reduction in moisture transmission and also help retard the staling rate of bread which is owed to the antifungal property [4].

Chitin has also found application as an antioxidant for food materials. One of the main ways the protein in foods deteriorate is under the influence of lipid oxidation. Chitin oliogomers (NA-COSs) is produced by acidic hydrolysis of chitin. This product shows substantial cellular antioxidant effects [6].

It is evident that Chitin and chitosan has a variety of applications in the food packaging industry and studies related to these compounds can help find further applications that will definitely prove useful to the industry[3].

C. Nano Technology In Food Science

Silver nanoparticles are widely used in the nanocomposite industry as antimicrobials and have also been approved by the US FDA (Food and drug administration) for use in food packaging and contact materials [6]. Low density polyethylene and gelatin are most widely used in nanocomposites.

The figure 5.2 below summarises the implementation of nanocomposites. Though research is still yet to be done related to the safety aspect of nanotechnology in food packaging one must not completely ignore this field with so much potential to contribute[16].

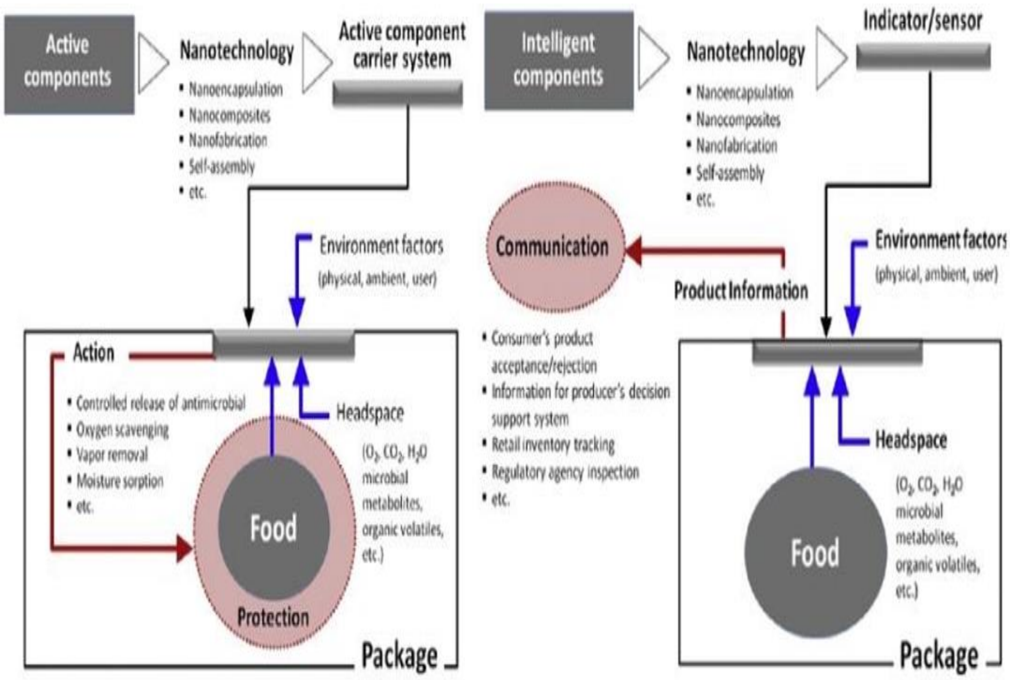

Fig. 7: Development of nanotechnology and its application in intelligent packaging

VI. SUMMARY

In this paper, we have studied the recent and popular materials, manufacturing processes and the various active food packaging systems used within the industry. A clear selection has been made in terms of the above parameters. Sustainable bio-plastics for minimal carbon footprint manufactured using suitable processes that are commercially viable, have been selected. These products are further improved by researching their design criteria and adding a further film/coating to improve on their functionality (antimicrobial, antioxidants). Further research on implementation methods needs to be done in regard to the added functionalities in order to make them more safer and consumer friendly. This paper aims to help future researchers in finding a suitable guide to their observations and problems.

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