Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/11037
DOI URL: http://dx.doi.org/10.21474/IJAR01/11037

RESEARCH ARTICLE

NATURAL POLYMERS; THEIR APPLICATIONS IN FOOD, COSMETIC AND PHARMACEUTICAL INDUSTRIES

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Manuscript Info

Manuscript History
Received: 22 March 2020
Final Accepted: 25 April 2020
Published: May 2020

Key words:-
Natural Polymers, Polymers in Food, Polymers in Pharmaceuticals

Abstract

Every formulation or product is made up of two main constituents that are Active Ingredients (AI) and Excipients. Active Ingredients are known to be the main ingredients which are responsible for any desirable effect whereas, excipients are the ingredients which are used to formulate any preparation alongside the active ingredients for stabilization of the product. In industries, polymers are generally used as excipients and play a vital role in pharmaceutical, cosmetics and food preparations. Polymers are classified into three sub-types that are natural polymers, synthetic polymers and semi-synthetic polymers where natural polymers are proven to be more suitable over synthetic and semi-synthetic polymers in preparations or formulations because of their characteristics of Sustainability, Biodegradability, Bio-safety, No side effects and don't have any Drug Release associated problem and many more. Natural polymers are used in several industries such as pharmaceutical, food, non-food and cosmetic industries and act as thickening agent, rate controlling agent, taste masking agent, protective or stabilizing agents & many more as per the requirements. Some of the examples of natural polymers are agar, tragacanth, gum acacia, xanthan gum, starch, pectin, locus bean gum, carrageenan, cellulose, inulin, gelatin, alginates, guar gum, psyllium, collagen, chitin and etc.

Introduction:-

The word polymer is derived from two Greek words that are 'poly' means many & 'meros' means units of high molecular masses. A polymer is a large molecule simply called as macromolecules composed of small structural sub-units known as monomers. These sub-units are interlinked by covalent bonds. Monomers are generally classified as olefinic (containing double bond) and functional (containing reactive functional groups) for which different polymerization methods are utilized. If two, three, four, or five monomers are attached with each other, the product is known as a dimer, trimer, tetramer, or pentamer, respectively. The chain of 30 to 100 monomeric units are called as oligomer whereas, the chain of more than 200 monomers are called a polymer. The process by which monomers form polymer is known as polymerization. (1) Polymers are classified as synthetic, semi-synthetic and natural polymers where natural polymers are predominantly preferred because of their attractive pharmaceutical applications such as biodegradability, sustainability, bio-safety, availability and many more.(2)

Understanding the role of polymers as excipient is important for the manufacturer, pharmacist, pharmaceutical scientists who deal with manufacturing of pharmaceutical products, food and cosmetic products on a daily basis.

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Having a basic understanding of polymers will give you the opportunity to not only familiarize yourself with the function of drug products but also possibly develop new formulations or better drug delivery systems.

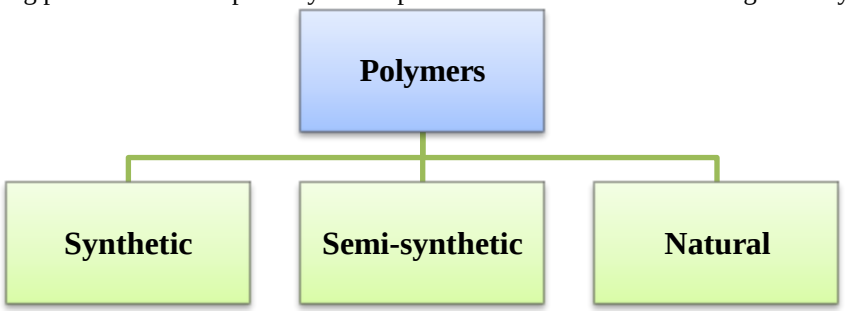

Fig 1:- Classification of polymers.

Here, we have some sources of various kinds of polymers along with their examples:

Natural polymers:

These polymers are generally found from plants and animals sources. Examples are proteins, cellulose, starch, resins.

Semi-synthetic polymers:

These polymers are obtained from natural polymers bysimple chemical treatment to change the physicalproperties of natural polymers like Starch, silicones.

Synthetic polymers:

The fibers which are synthesized in laboratory bypolymerization of simple chemical molecules are calledSynthetic polymers, example: Nylon, polyethene, Polystyrene, Synthetic Rubber, PVC, Teflon etc.

The specific applications of natural polymers inpharmaceutical formulations include their use in themanufacture of:

1. Solid implants
2. Films
3. Beads
4. Micro-particles
5. Nano-particles
6. Inhalable and injectable systems
7. Viscous liquid formulations and many more. (2-4)

Within above mentioned dosage forms, polymeric materials havefulfilled different roles such as binders, matrix formers ordrug release modifiers, film coating formers, thickenersor viscosity enhancers, stabilizers, disintegrants,solubilizers, emulsifiers, suspending agents, gelling agentsand bio-adhesives in pharmaceuticals. (5)

Besides pharmaceutical industry natural polymers also have various applications in other industries such as in food, non-food and cosmetic industry. Where, in cosmetic industry natural polymers act as a potential anti-aging constituent. (5)

Applications of natural polymers over synthetic & semi-synthetic polymers:

Biodegradable:

Natural polymers are synthesized by all the living organisms and doesn`t show any adverse effects on theenvironment or human being. In contrary, synthetic and semi-synthetic polymers, being prepared by the help of chemicals and have side effects on atmosphere as well as on the human being.

Biocompatibility and non-toxicity:

Chemically, nearly all of these natural polymers arecarbohydrates in nature and composed of repeatingmonosaccharide units. Hence they are non-toxic ascompared to synthetic and semi-synthetic polymers.

Fig 2: Pharmaceutical role of polymeric materials

Economic:
Natural polymers are cheaper and their extraction cost isless than any other synthetic materials.

Availability:
Natural polymers are growing in the form of herbs inmany counties being economical than synthetic polymers and having no side effect and keeping in view their hugeapplication in many industries, they are produced in large quantity hence their availability is ensured than synthetic and semi-synthetic polymers. (6)

LIMITATIONS OF NATURAL POLYMERS:
Microbial contamination:
Natural polymers are extracted from plants and if accidentally exposed to an externalenvironment during extraction process there are chances of microbialcontamination.

Quality variation over different batches:
In manufacturing of synthetic type polymers there are fixed amount of ingredients while in natural polymers amount of ingredient dependent on environment and various biotic and A-biotic factors.

Uncontrolled Hydration:
Variations in several factors liketimes, region, species and climate leads to the variation in percentage of chemicalconstituents present in a natural materials. (6)

Slow Process:
Natural polymers have a slow rate of production because their rate of production depends upon the environment andmany other factors.

Contamination due to metals:
There are possibilities of Heavy metal contamination in herbal materials &herbal excipients. (7)

Classification of natural polymers:
Natural polymers are classified into 2 types:
1. Polysaccharides
2. Proteins (Which arefurther classified as following, refer table-1)

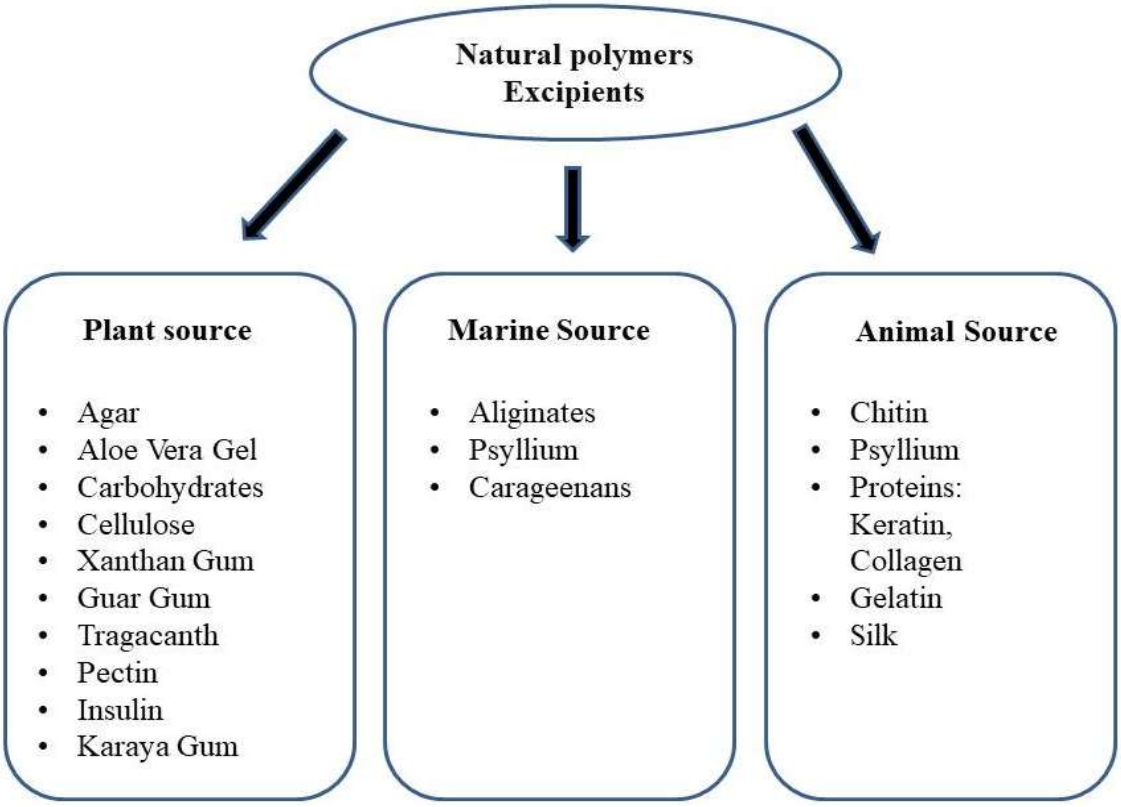

Table-1:- Classification of natural polymers (polysaccharides and proteins) into further sub-types (8).

Natural polymers according to their origin, properties and uses:
Natural polymers used in various pharmaceutical industries are tabulatedwith their sources and properties and their description is given in Table 2:

1) AGAR:
Agar or agar-agar is a polysaccharide obtained from the plant origins like Gelidiumamansii(Gelidaceae) and it can also be obtained from several other species of red algae like gracilaria (Gracilariaceae) and Pterocladia (Gelidaceae). (9) Chemically, it is mixture of Agarose and Agaropectin where agarose is a linear polymer made up of the repeating monomeric unit of agarobiose. Whereas,Agarobiose is a disaccharide made up of D-galactose and 3,6-anhydro-L-galactopyranose.While, on the other hand Agaropectin is aheterogeneous mixture of small acidic molecules.

Industrial applications of Agar:

1. Agar can be used as a Suspending agent, emulsifying agent, gelling agent in suppositories preparation, surgical lubrication, tablet disintegration and many more.
2. It is used in the preparation of jellies, confectionary items, tissue culture studies, and in microbiology study.
3. It also acts as an appetite suppressant and laxative. (10)

S. no.	Polymers	Source	Properties	Reference
1.	Agar	Present in cell wall of algae agarophyte	Thickener, Laxative, Appetite suppressant	9-10
2.	Pectin	Present in cell wall of terrestrial plants	Thickening properties, Stabilizing properties	11-15
3.	Starch	Potatoes, maize, rice, wheat, etc.	Act as disintegrant, Act as binder	9 ,16-17
4.	Guar Gum	Guar beans	Thickening properties, Stabilizing properties	9, 18-22
5.	Tragacanth	Dried gum obtained sap of several species of genus Astragalus	Thickening properties, Stabilizing properties, Binding property	23
6.	Gelatin	Obtained from animal body parts like bone and skin	Used as a carrier, Coating or separating agent	24-28
7.	Alginates	Present in cell wall of brown algae	Thickening Properties	29-33
8.	Psylliuim	Seeds of Plantago	Thickening properties, Production of mucilage	34-35
9.	Carragenan	Extracted from red edible sea Weeds	Thickening properties, Stabilizing properties, Binding property	19, 36-38
10.	Cellulose	Present in cell wall of green plants, algae and Oomycetes	Thickening properties, Stabilizing properties	39-43
11.	Gum Acacia	Obtained from the stem and branches of acacia Arabica	Act as a stabilizer, thickener, flocculants and emulsifiers, adhesive properties	44
12.	Chitin	shells of crustaceans (crab, shrimp and lobster)	Sustain drug release properties, mucoadhesive properties.	45-46
13.	Collagen	bones, skin, and connective tissue of animals including cattle, fish, horses, pigs, or rabbit**s**	water holding properties, oil absorption, gelling properties, foaming properties and emulsifying properties	47-48
14.	Xanthan Gum	obtained from gram-negative bacterium Xanthomonascampestris	Emulsion stabilizing properties, binding properties, thickening properties.	49-50
15.	Locust Bean gum	Extracted from seeds of carob tree	Thickening properties, gelling properties.	51

Table 2:- Natural Polymers and their uses.

2) STARCH:
Starch is a polysaccharide obtained from the natural origin such as green plants, seeds and underground organs of the plants. Sources of starch used in several industries include maize (Zea mays), rice (Oryza sativa), wheat (Triticumaestivum), and potato (Solanum tuberosum). (9)Chemically, Starch is a carbohydrate consists of a long chain of glucose units linked together by glycosidic bonds. It consists of two polymers, namely amylose and amylopectin where amylose is a Non branching helical polymer consisting of long chain of α-1, 4 linked D-glucose monomers whereas, amylopectin a highlybranched polymer consisting of long chain of both α-1,4 and α-1,6linked D-glucose monomers. (16)

Industrial applications of starch:
Thermoplastic starch is used in several industries such as packaging, containers, mulch films, textile sizing agents and adhesives industries. (52)Starch also acts as a disintegrants and binders. (17)

3) GAUR GUM:
Guar gum is also known from its several names such as guaran, clusterbean, Calcutta lucern, Gum cyamposis, and Cyamopsis gum, Guarina, Glucotard and Guyarem. (18)Guar gum is the endospermic powder obatained from the seeds of CyamopsistetragonolobusLinn. (Leguminosae). (9)Chemically, guar gum is a natural polysaccharide composed of the sugars galactose and mannose.

Industrial applications of gaur gum:
Several modifications in guar gum are applied for accessing the drug delivery system. (19)Derivatives of guar gum like Carboxy-methyl guar is used in the preparation of transdermal therapeutic system. (21)

4) GELATIN:
Gelatin is a protein obtained from the animal sources by degradation of collagen. It is a high molecular weight polypeptide consists of 19 amino acids. (53-54) Also it is known for its characteristic property of water solubility.

Industrial applications of gelatin:
Gelatin act as emulsifiers, foaming agents, colloid stabilizers, biodegradable film-forming materials, and microencapsulating agents. (55)It is also used as a carrier, coating and separating agents. (28)

5) COLLAGEN:
Collagen is a protein obtained from the animal sources especially from animal connective tissues. (56) The most familiar sources of collagen are pig skin, bovine hide, and pork and cattle bones. (57)Chemically, there are 27 types of collagen composed of different polypeptides where some of the common constituents are glycine, proline,hydroxyproline and lysine. (56-57)There is flexibility in a collagen chain according to the glycine content. (56)

Industrial applications of collagen:
Collagen is used in ophthalmic formulations to regulate drug delivery systems for slow release of incorporated drugs. (58)It is also used in tissue engineering including skin replacement, artificial blood vessels, bone substitutes and valves. (59)

6) ALGINATES:
Alginate is a polysaccharide obtained from natural origin like brown see-weed and has a characteristic feature of water solubility.Chemically, it is composed of 1–4 linked–L-glucuronic and -D-mannuronicacid with their residues. (29-30)

Industrial applications of alginates:
Alginate act as an encapsulating agent for controlled drug delivery to mucosal tissue. (32)Mesalazintablets primarily composed of alginate play vital role in u intestinal drug delivery system. (31)In drug delivery system it is also used to prepare muco-adhesives.In several other industries it is used as a thickening agent. (33)

7) PSYLLIUM:
Psyllium is also a polysaccharide obtained from natural origin like seed coat of Plantago ovata by applying physical forces on the outer layer of the seeds.Chemically, it is a mixture of several polysaccharides: pentoses, hexoses and uronic acids. (34)

Industrial applications of psyllium:
Psyllium acts as a thickening agent and also used to produce mucilage.It acts as a binding agent in preparation of tablet. (34)Psyllium is a bulk-forming laxative used to treat constipation. It is also used in combination with other excipients such as hydroxypropyl methylcellulose to prepare drug delivery systems for medication of bacterial infections. (35)

8) CELLULOSE:
Cellulose is a polysaccharide and obtained from the natural/plant origin mainly from plant cell wall which is made up of cellulose, hemicelluloses and pectin. (61) Chemically, cellulose is linear polysaccharide made up of long chain β(1→4) linked D-glucose having molecular formula $(C_6H_{10}O_5)_n$. (60)

Industrial applications of cellulose:
Celluloseis primarily used as a diluents or binder in tablets for the purpose of granulation and direct compression processes. (62) Other derivatives of cellulose like carboxylated methyl cellulose are also used as a binder in drugs formulations, film-coating agent, ointment base etc. (39-41) They also exhibit thickening properties and stabilizing properties in pharmaceutical preparations. (39,40)

9) CHITIN:
Chitin is also a polysaccharide but obtained from animal origins from the skeletal material of the invertebrates. Organisms known for its much availability are mollusks, annelids & arthropods. Chemically, chitin is combination of amino group and acetyl group. (9)

Industrial applications of chitin:
Nano-particles and micro particles of chitin are used in pharmaceutical industries as a controlled-drug release agent. (63) It also exhibit muco-adhesive properties. (46)

10) XANTHAN GUM:
Xanthan gum is an extracellular Polysaccharide having high molecular weight and produced by the fermentation of the gram-negative bacterium Xanthomonascampestris. Chemically, it is made up of D-glucoseResidues and D-mannose- D gluronic acid. (64)

Industrial applications of xanthan gum:
Xanthan gum is known for its suspending and stabilizing properties which is further used in oral and topical formulations, cosmetic & food industries.It is also used in preparation of sustained release matrix tablets.It also exhibits emulsion stabilizing properties & binding properties in pharmaceutical preparations. (65)

11) GUM ACACIA:
Gum acacia is also known with its several names such as Gum Arabic, Gum Sudani, Senagal Gum, Indian Gum, and many others. It is obtained from the stem and branches of acacia Arabica. (66)Chemically, it is a complex mixture of glycoprotein and polysaccharide consisting of arabinose and galactose.

Industrial applications of gum acacia:
It is used as a stabilizer in food and soft drink industries.It is used as key ingredients in traditional lithography, paint production industries and various textile industries.It is also used as a binding agent, emulsifying agent, suspending or viscosity increasing agent in pharmaceutical industries and cosmetic industries. (67)

12) Carrageenan:
Carrageenan is a linear sulfated polysaccharide obtained from the red edible seaweeds by extraction process. There are three varieties of carrageenan on the basis of their degree of sulfation. Kappa-carrageenan, iota-carrageenan, lambda-carrageenan. (68-69)Chemically, they are a high molecular polysaccharide made up of repeating galactose units and 3, 6 anhydrogalactose, both sulfated and non-sulfated. (69)

Industrial applications of carrageenan:
Carrageenan has a wide application in food industry. It is used as EU additive. (70) Technically, it is considered as a dietary fiber. It is used as a thickening agent and stabilizing agent in many industries.It is also used as inactive excipients in formulation of pills and tablets. (71- 72)

13) PECTIN:
Pectin is a structural acidic hetro-polysaccharide present abundantly in the primary cell wall of terrestrial plants. Commercially, it is extracted from the citrus fruit and chemically, it is made up of galacturonic acid (a sugar acid derived from galactose). (73)

Industrial applications of pectin:
It is commonly used in food industry as a gelling agent for the preparation of jellies and jams. It is also used to stabilize acidic protein drinks, such as yogurt. (74) In medicines, it is used in throat lozenges as a demulcent. (75)

14) TRAGACANTH:
Tragacanth gum is also known with its several names such as Shiraz gum, Shiraz, Gum elect or Gum dragon. (76) It is a polysaccharide obtained from the dried sap of several species of Middle Eastern legumes of the genus Astragalus, including A.adscendens, A.gummifer, (77)A. brachycalyx, (78-79) and A. tragacantha. It is a viscous, odorless, tasteless and water-soluble in nature.

Industrial applications of tragacanth:
It is used in pharmaceuticals and foods as an emulsifier, thickener, stabilizer, and texturant additive.It is also used in incense-preparation as a binder to hold all the powdered herbs together.Occasionally, it is used as a stiffener in textiles industries.(80)

15) LOCUST BEAN GUM:
Locust bean gum is also known as carob gum, carob bean gum and carobin. It is a hydrocolloidal polysaccharide obtained from the seeds of carob tree. (81) Chemically, it is composed of galactose and mannose units combined through glycosidic linkages. (82)

Industrial applications of locust bean gum:
It is used as a thickening agent and gelling agent in food and pharmaceutical industries.It is also used as a sweetening agent in food industries. (83)It is also used as an additive in the preparation of shoe polish and insecticides. (84)

16) INULIN:
Inulin is a natural polysaccharide obtained from the wheat, onion, bananas, garlic, asparagus and chicory. (85) It is used by some plants as a means of storing energy. Chemically, it is a heterogeneous collection of fructose polymers consists of glucosyl moieties and repetitive fructosyl moieties.

Industrial applications of inulin:
Inulin is used as a dietary fiber ingredient to improve the nutritional value of manufactured food products.(86)It has been also used to prepare biodegradable colon-specific films in pharmaceutical industries. (15)

Role of natural polymers in cosmetic industries:
Polymers are routinely used in many personal care and cosmetic products. The applications take advantage of the various properties of various properties of these polymers to impact unique benefits to their formulations. The range of properties is as varied as the class of polymers that have been utilized. Using polymers, cosmetic chemist can create high quality products. Natural polymers are used is used in wide range of cosmetic products as film-formers, emulsifiers, thickeners, modifiers, protective barriers, and as aesthetic enhancer. (17)

In cosmetic industries natural polymers are frequently used as excipients in products and providing the benefits which is not available before like water resistance or “sweat-proof” characteristics and other long lasting properties. These polymers are used according to their chemical properties to obtain the required characteristic in any formulation.

Generally, in cosmetic industry these natural polymers are used as a thickening agent, binding agent, emulsifying agent, stabilizing agents and disintegrating agents as mention in table 4.1. for example Aloe Vera, Tragacanth, Guar Gum etc.

Besides this, natural polymers are also used as a constituent in anti-aging products and hair products. For instance; xanthan gum is widely used in anti-aging products while, on the other hand polysaccharide (starch & cellular derivatives) and hydrolyzed proteins are used in hair products preparation. (17)

In personal care products and cosmetic products a large number of natural or even synthetic polymers are used as anti-oxidant.Some of the commonly used natural antioxidantsare grape seed extract, horse chestnut extract,celery extract, and cucumber extract etc. Generally, Antioxidants are used to scavenge freeradicals, as free radicals are known to contribute to the aging process and we can also say that the anti-oxidant play a major role in cosmetic as anti-aging agent.(103)Besides, these one more component is commonly added in cosmetics and personal care products (PCP) known as surfactants. Surfactants provide stability to the products and are also used for cleansing, foaming, thickening, emulsifying, solubilizing, penetration enhancement, anti-microbial effect and other special effect. The key property of surfactant molecules which makes them useful in cosmetic is that they are compatible with both water and oil.

Role of natural polymers in food industries:
Natural polymers play an important role in food industries in the context of formulated foods. Natural polymers exist in two forms that are linear and branched where branched polymers with high order structure are more applicable in industries. Most of the food items are made up of three main naturally occurring polymers, primarily polysaccharide (i.e. starches &cellulose) and polyamides (proteins) as well as small amount of polynucleotide (DNA & RNA) found in cellular material. Besides, nutritional values they are also used as additive and ingredient in food formulations having a specific function.(87)

These specific functions of natural polymers added to food are classified into two main categories:

1. The creation and stabilization of food microstructure.
2. Additional physiological and biological function. (87)

The creation and stabilization of food microstructure:
On perspective of the functional roles of natural polymers the creation and stabilization of food microstructures are roughly classified into three sub-types:-

1. Emulsifiers &Stabilizers
2. Thickeners
3. Gelling agents

The main role of natural polymers in formulated food is to create and maintain the texture and microstructure of food.Further quality improvements of existing foods and the creation and formulation of new food products are largely based on interventions in micro-structural level.(88)These micro-structural elements are often based on natural polymers and their function in formulations. Typically, natural polymers are dispersed in water creating viscous solutions, dispersions, gels and stabilizers for emulsion oil droplets as well as function in gas bubbles formation in foams, etc.(89)

Emulsifiers and Stabilizers:
Almost every formulated food products which we enjoy in our day to day life is based on emulsions and foams. In food products where, there is a need to establish a uniform dispersion or stabilize an emulsion or foam by increasing its kinetic stability, emulsifiers are used. They are also used toprevent baked goods from becoming stale, to preventcream sauces and mayonnaise from separating, to keep flavors suspended, andto stabilize ice creams. Emulsions or foams can be prepared by using four basic ingredients that are:

1. Continuous phase
2. Dispersed phase
3. Mechanical energy
4. Emulsifiers

To make an emulsion dispersed phase is dispersed in a continuous phase in form of droplet and bubble and creates an interface between the two phases. The creation of this interface requires mechanical energy from an emulsifying device and emulsifier whichhelp to lowering the interfacial tension between the two phases assisting in the emulsification process and/or a stabilizer that preserves the newly formed interface. Emulsion may be of two type oil in water (O/W) and water in oil (W/O) whereas; foams are dispersion of air in water (A/W) type.

Thickeners:
In food industries and systems thickeners are widely used, unlike emulsifiers and stabilizers used to produce and stabilize emulsions droplets and foams, thickeners are also added to increase the viscosity of the food without necessarily modifying product properties. Thickeners increase the consistency to prevent multi-component products from separating such as reducing the rate of creaming. Examples of natural polymers commonly used as thickeners in industries presented in Table 4.1. The viscosity of the solution containing natural polymer in it depends on the type and concentration polymer.

Gelling agents:
Although all hydrocolloids have a key chemical property to increase the viscosity of aqueous dispersions, a few natural polymers have an additional property of being able to form gels.Examples of some common natural polymers used as gelling agents in industries are presented in Table 4.1.Gel formation arises with the associationor cross-linking of polymer chains, thereby creating a three-dimensional networktrapping water within it to form a semi-rigid structure which resist to flow.Natural polymer-based gels are generally visco-elastic in nature exhibiting characteristics ofboth liquids and solids depending on the applied deformation stress.

Additional physiological and biological functions:
Effects of natural polymers on food and human health can be understood by the following parameters:

a) Effect of natural polymers on health:
Natural polymers are primarily and widely used for addition in various classical food formulations industries as mentioned above. Some of the soluble non-starch polysaccharidessuch as pectin,guar gum, ispaghul, beta-glucan, inulin, and gellan natural polymers also have additional health benefitsthat arise from the specific structural properties they exert in the food matrix.The effects of these polysaccharides are dependent on both the dose ingested andwhether they are bound or free to form viscous solutions.(90)

Generally, the health beneficial effects from natural polymers are achieved with higher levels of usage of them as compared to typically used in food products. For example, the typical usage level of guar gumis<1 % in food products but to achieve health benefits, the levels must be up to around 3–5 % which unfortunately cause negatively slimy mouth feel.(91)

b) Intestinal effect of natural polymers-Prolonging Satiety and Inducing Weight Loss:
There are many drugs known which are usually designed to facilitate weight loss but rejected due to limited efficacy, high drop-out rate in long-term treatment, concerns of side effects and safety.(92) Natural polymers in Gastro-intestinal tract affect the absorption of nutrients by mechanically hindering the process of digestion &leads to promising effects of weight loss and maintenance. For example; gaur gum in intestine absorbs the carbohydrate content by forming gel and thereby decreases the rate of glucose absorption into the hepatic portal vein, Thylakoid membranes obtained from spinach retard uptake and passage of glucose, larger carbohydrates, and proteins.(93) Thylakoids are attached to the mucosal surface,hindering absorption of nutrients by steric hindrance. Thylakoids have also beendemonstrated for prolong absorption of lipids by specifically inhibiting pancreaticlipase and colipase.(94)However, alginate doesn't show any effect on appetite sensation.(95)

c) Effect of Natural Polymers on Blood Cholesterol Levels:
Hydrocolloids have the potential to increase viscosity and reduce the absorption of bile byentrapment of molecules inside the polysaccharide network. Bile salts are synthesized from cholesterol in the liver hence, stored in the gall bladder and secreted into the intestine after meals to promote digestion and absorption of fat. Synthesis of bile is an energy consuming process. When bile is trapped in a polysaccharide gel in the intestine, they go into the GIT without being reabsorbed, and the systemicbile pool is decreased. Natural polymers like pectin, psyllium, beta-glucans and guar gum has been demonstrated to reduce total cholesterol and LDL cholesterol level in human body.(96-98)

d) Bioavailability can be improved by natural polymers:
Several Natural polymers and essential nutrients, such as vitamins are poorly soluble in water and these characteristics together limit their wider application in the food industry. To overcome these challenges, a wide variety of colloidal delivery systems are used to improve physicochemical stability, process ability, and bioavailability of food and beverages products.(99,100)During transit through the GIT (gastro-intestinal tract) the structure of food emulsions are largelymodified before entering the intestine where most nutrient absorption is takingplace. Food emulsions are prone to micro-structural changes, such as flocculation,coalescence, and creaming during digestion and the intensity of these processesgreatly affect the delivery efficacy such as bioavailability of the nutrients. (101)

e) Anti-oxidative properties of natural polymers:
Besides, biological activity within the human gastro-intestinal tract (GIT), some natural polymers also has exceptional biological function and properties which is used to attain anti-oxidative and antimicrobial properties in food formulations. For example, oleosins and soy fibers have anti-oxidative properties hence both of them are used as anti-oxidative agents in formulations.

Lipid oxidation is a major problem for food manufactures as oxidation products are associated with decreased food quality in terms of taste, texture, appearance, and shelf life.To overcome this lipid oxidation oleosin, a protein stabilizing oil bodies inside the seeds of oilplants such as canola can be used as both emulsion stabilizer and anti-oxidative agent. (102)

f) Future aspects of polymers:
As we all know in future there will be many crisis related to energy & resources, food, health, mobility, infrastructure and communication where polymers may play a key role to tackle these challenges. Probably Polymers will be the suitable material in new millennium for production of sustainable products.
The use and development of natural polymers is likely to expand in coming years, there may be a transfer of sources from existing to another due to current crisis like sourcing issues, varying prices, and consumer preference changes. There are some parameters that may help to adapt sustainable development in context of natural polymers as mentioned below:

g) Creation and adoption of new technologies:
The advent of novel technologies such as micro/ nano-encapsulation in the food sector has allowed for the application of many ingredients, such as modified starches, hydrocolloids, and macromolecular emulsifiersto create core shell materials, or even serve both as shell material and as binding agents that improve process stability and textural properties of the final product.(104,105)

h) A significant shift from synthetic to natural ingredients:
Now a day's health and wellness are the most familiar topic of major concerns therefore consumers prefer to use natural substances or ingredients to resist health related problems which has a significant impact to shift from synthetic to natural ingredients. This may lead producers to develop all-natural products or to partially replace synthetic ingredients with natural ingredients/additives in their offering products.(104)

i) Enhancement in consumption of convenient and performance foods:
There is a growth in the convenience food and prepackaged food which creates more opportunities for natural polymer based products, textural food ingredients and especially in usage of "natural" ingredient trend. Primitively natural polymers are used to maintain and control the stability and improve the texture of products whereas, many consumers are getting aware right now about the nutritional and health benefits of natural polymers.(105)
Although there would be an increase in natural polymers based micro-gels this is because of the fact that micro-gels can replace fats as well as control rheology and texture of products, able in targeted delivery,controlled release, and satiety control applications.

Conclusion:-
Now a day, use of polymers in various industries & products are essential and common as well to regulate the properties of products and minimizing stability related issues and many more. On the basis of analyzed data natural polymers to be proven more compatible substitute amongst synthetic and semi-synthetic polymers because of number of their application over them in industries & products. Any product which is prepared with synthetic

polymers can be upgraded in term of quality, less toxicity and high drug delivery responses if, replaced with required natural polymers.Natural polymers are also suitable to overcome side effects arise due to synthetic polymers in any formulation.

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