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## Review Article

### Exopolysaccharides and their applications in food processing industries

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#### Abstract

Production of exopolysaccharides (EPSs) has been reported in prokaryotes and eukaryotes. Microbial exopolysaccharides have increased interest as another category of microbial products utilized in the pharmaceutical, biomedical, and food industries. Investigators are considering replacing synthetic food stabilizers with organic ones by investigating EPS in fermentation-based dairy industries. Particularly for the enhancement of the rheology of fermented food items, EPS is being used. EPSs are considered a natural texturizer and a good alternative for other artificial or new biopolymers utilized in foodstuff as a gelling agent and for suspending and thickening food. These EPS are used abundantly in fermented food and dairy industrials for quality improvement. The main microbial exopolysaccharides viz. dextran, xanthan, pullulan, gellan, curdlan, and scleroglucan have a versatile reputation and various food processing applications in industries. The review discusses the distinctive physical properties of EPSs that mainly determine their application in food industries and the health benefits of EPSs.

#### Keywords

Exopolysaccharides; biopolymer; physical properties; functions of EPSs; health benefits; food applications; food industries

#### Abbreviations

EPS – exopolysaccharide  
LAB – lactic acid bacteria  
USFDA – United States Food and Drug Administration  
HPMC – hydroxypropyl methylcellulose  
LBG – locust bean gum

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## Introduction

Exopolysaccharides, comprised of branched, repeated sugar units or sugar derivatives, quickly evolve as new and industrially significant biomaterials. Exopolysaccharides are further categorized based on monosaccharides units or their derivatives as homopolysaccharides (dextran, curdlan, and pullulan) and heteropolysaccharides (xanthan and gellan). Owing to the distinctive structures and unique compatibility, microbial exopolysaccharides come up with a wide array of industrial applications in diverse fields that tend to range from agricultural biotechnology to the pharmaceutical and food industries. Microbial polymers emerged in the 1960s, and their commercial use has increased considerably since then. The microbial EPS plays a significant role in the cellular associations, nutrition, and micro-and macro environment (Kleber et al. 2015). They have been employed in the food, detergents, beverages and textile, pharmaceutical trades, cancer treatments, drugs, and fermentation media formulation. They have also been used in biotechnology, agriculture, paint, paper, and petroleum industries (Fenibo et al. 2019). EPS formed by lactic acid bacteria (LAB) plays a prominent part in producing cultured milk products, viz. cheese, yogurt, milk-based desserts, drinking yogurt, and cultured cream (Mende et al. 2016). LAB's production of exopolysaccharides varies widely in chemical composition, charge, quantity, side chains, molecular mass, and molecular rigidity. Firmness and creaminess are significant sensory matters relevant to the consumer's preference for dairy products. EPS might perform as texturizers and stabilizers by enhancing the thickness of the ending product and, then, by combining water hydration and new milk components, such as micelles and proteins, to strengthen the inflexibility of the casein network (Tabibloghmany et al. 2014). As a result, EPS can reduce the synthesis of toxic by-products and increase product quality. Besides, EPS has also been found to impact intestinal health significantly. EPS producing *S. thermophiles* (Broadbent et al. 2003) can improve the efficient characteristics of Mozzarella cheese; however, they aren't phage-proof. EPS enhances the value of the food being processed. It communicates with water molecules and regulates the rheological behavior and natural

strength of foodstuff. The advancement of nutritional supplements has provided another fantastic prospect for the food processing industry. The crucial problem in nutraceuticals is the stabilization of efficacy and the apparent regulation of the practical components in the product. The various application and functions of the main exopolysaccharides are shown in Table 1 (Mollakhalili Meybodi et al. 2015).

The livestock feed industry has used the significant suspension and constancy characteristics of EPS to transport liquid feed containing additional vitamins and more supplements that otherwise would have been sedimented during transport or storage (Morris et al. 2009). It has been shown that microbes such as *Alkaligenes sp.*, *Agrobacterium sp.*, *Acetobacter sp.*, and *Rhizobium sp* can co-synthesize two or more chemically distinctive exopolymers (Shukla et al. 2019). It includes exopolysaccharides with low molecular mass, such as  $\beta$ -1,2 glucans. Therefore, it is possible that, in response to a nearby surface, these additional polymers are synthesized and secreted. Subsequently, high molecular weight EPS formation is revealed in recent events such as colony maintenance and persistence (Sahana et al. 2018). Diversity research of cultivatable EPS producing marine ecosystem bacteria from Alang, India, indicates 22 genera with EPS production as high as 10.7g/L (de Moraes et al. 2010, Upadhyay et al. 2019). Therefore, the richness and distinctiveness of the maritime biosphere, which involves Antarctic sea ice, Arctic, and deep-sea hydrothermal vents, still hasn't been thoroughly explored sample opportunities for new polysaccharides to be discovered. For exopolysaccharides (EPS) production, numerous yeasts, fungi, algae, and bacteria are widely recognized. In this natural environment, the capability of microbes to produce EPS is a straightforward and reasonable action to particular difficulties.

EPS are explored from methanogens, halobacteria, hydrothermal vent bacteria, acidophilus, autotrophic organisms, and microbes from underground water and wastewater effluent. As possible sources of worthwhile biopolymers, including EPSs, some microbes isolated from extreme environments, like geothermal springs, saline lakes, Antarctic ecosystems, and deep-sea hydrothermal vents, have begun to be investigated

(Morris et al. 2009, Poli et al. 2011). Efficacious industrial usage of microbial EPS relies on manipulating natural characteristics relating to the solution rheology of EPS and the capability to form low concentration gel. Technological progress has directed the formation of the social value of bacterial polymers (Nwodo et al. 2012). Compared to synthetic polymers, polysaccharides produced from microbes are biodegradable and environmentally friendly. In industrial uses and manure removal or environmental usages, this contributes to their environmental friendliness.

**Table 1.** List of main exopolysaccharides and their applications and functions in food processing industries (Mollakhalili Meybodi et al. 2015)

Type	Application	Role	Reference
<b>Dextran</b>	Frozen products as a possible prebiotic agent	-The product's viscosity and viscoelastic properties are not impaired by the addition of dextran. The use of dextran as a prebiotic has increased <i>Bifidobacterium</i> counts.	(Lopez et al. 2005, Sarbini et al. 2014)
<b>Xanthan</b>	Frozen products beverages	-Improves reliability of freeze-thaw. -In addition to fibres, xanthan decelerated degradation responses with a protective effect.	(Palaniraj et al. 2011, Paquet et al. 2014)
<b>Pullulan</b>	Enhancement of other polysaccharides function edible film	The increased pullulan concentration decreased the flow activity index (n) of gel solutions and increased viscosity. The coatings slowed mould development and reduced the loss of weight, carotenoids, and deterioration and softening of fruit ascorbic acid. The film made by 10% pullulan is considered a good and efficient film.	(Eroglu et al. 2014)
<b>Gellan</b>	Emulsion based gels beverages	-High concentration of gellan emulsions primarily demonstrated an elastic behaviour producing flexible gels. -During fermentation, or post-fermentation treatment or recovery, native gellan may be partially deacylated by alkali, enzymes, or high temperature.	(Cho 2001, Lorenzo et al. 2013)
<b>Curdlan</b>	As a barrier during deep-fat frying	-Curdlan has a linear effect on moisture transfer, and reducing oil was demonstrated by adding curdlan. This influence of the curdlan was likely due to its thermal gelling qualities, and during frying, the heat-stimulated gel possibly worked as a barrier to oil and moistness. The noodle's chewiness, versatility, and durability were enhanced when curdlan was introduced.	(Funami et al. 1999)
<b>Scleroglucan</b>	Cooked starch pastes	-The syneresis was prevented by scleroglucan without affecting gelling properties, pH, colour, or hardness.	(Viñarta et al. 2006)

## Various EPSs and their applications in food processing industries

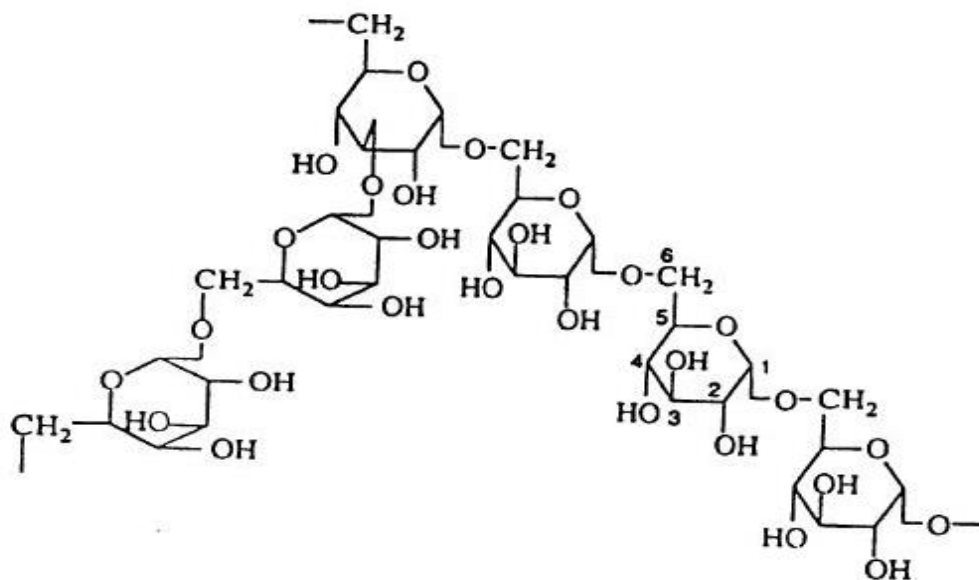
### Dextran

Dextrans are microbial homopolysaccharides with alpha-linked D-glucopyranosyl recurring units with a linear backbone. Dextrans belongs to an  $\alpha$ -D-glucans containing primary chain  $\alpha$ -(1-6) bonds and varying quantities of  $\alpha$ -(1-2),  $\alpha$ -(1-3), or  $\alpha$ -(1-4) branched bonds (Fig. 1) (Nouvel et al. 2003). It has gained global popularity among various EPSs, because of its decomposable and biocompatible

properties (Patel et al. 2010, Aman et al. 2012, Varshosaz 2012). Before the 1950s, dextran was explored as a dietary supplement. The US FDA (United States food & drug administration) recently listed dextran in the category of GRAS (generally recognized as safe) food additive. Usually, dextran is employed in various food products for gel, viscosity, texture, and emulsification (Leemhuis et al. 2013). Commercially, LAB dextran is applied in the food processing industries and pharmaceutical sectors.

**Table 2.** Applications and functions of Dextran in food industries (Ramawat et al. 2015)

Application	Function	References
<b>Bakery</b>	Enhances freshness, mouthfeel, softness, quality of crumbs, the volume of the loaf, and shelf life	(Katina et al. 2009)
<b>Ice cream</b>	Act as cryoprotectant	(Naessens et al. 2005)
<b>Confectionary</b>	Improves viscosity and moisture retention and prevents jelly candies, gelling agents in gum, and sugar crystallization	(Maina et al. 2011)
<b>Frozen foods</b>	Protection from chemical alterations and oxidation and maintenance of texture and flavour	(Bhavani et al. 2010)
<b>Fermented dairy products</b>	Increases reduce syneresis and creaminess, and viscosity	(Mende et al. 2013)
<b>Prebiotics</b>	Prebiotics	(Olano-Martin et al. 2000, Rao et al. 2013, Sarbini et al. 2013, Das et al. 2014, Tingirikari et al. 2014)
<b>Reduced-fat cheese</b>	Enhances water binding and improves moisture content in the ingredients without fat	(Awad et al. 2005)
<b>Protein–dextran conjugates</b>	Improves protein emulsifying, foaming, gelling, and solubilization characteristics by Maillard reaction	(Zhang et al. 2012, Chen et al. 2014, Spotti et al. 2014)



**Figure 1.** Chemical structure of dextran. Reprinted with permission from (Nouvel et al. 2003). Copyright @ American Chemical Society

Though, dextran has a range of possible applications in photography, film processing, fine chemicals, textile, paper, oil, and cosmetics industries (Naessens et al. 2005, Leemhuis et al. 2013). Because of its diversity, the application of different LAB-produced dextran can depend upon well-known physicochemical and chemical characteristics. Applications of dextran in the food processing sectors are listed in Table 2 (Ramawat et al. 2015). For the formulation of food products, long-chain highly molecular mass polysaccharides dissolve in water to enhance their rheology (condensing, gelling) or physicochemical properties (suspension of particles and emulsion stabilization) are significant.

Dextran has become a desirable dietary supplement in an evolving customer trend toward healthy and additive-free food products. The manufacture of dextran in food industries without any limitation is based on microorganisms such as *Lactobacillus sanfrancisco*, *Lactobacillus plantarum*, *Saccharomyces cerevisiae*, and *Leuconostoc mesenteroides*. Different applications of dextran in food processing industries are as follows:

### **Bakery**

The interest is rising in the implementation of dextran to improve bread quality and its rheological properties (Galle et al. 2012, Wolter et al. 2014).

The rising awareness of sourdough culture offers innovative chances of its application in the bakery industry. The cleanness, mouthfeel, consistency, capacity of the loaf, shelf life, and smoothness, of sourdough wheat bread were enhanced by *in situ* dextran production from *Weissella sp.* and *Leuconostoc mesenteroides* (Katina et al. 2009, Galle et al. 2012). Dextran was shown to possess a high molecular mass and little branched bonds for sourdough application (Lacaze et al. 2007). Dextran also has a possible application in the baking industry to produce food products with no gluten for patients experiencing celiac disease (Schwab et al. 2008, Galle et al. 2010, Rao et al. 2013).

### **Ice cream**

As dextran is helpful as a stabilizer in frozen dairy products, the ice cream mixes with dextran to access its utility with this microbial polysaccharide in varying concentrations were tested and prepared through mechanical, physical, and sensory means. This microbial polysaccharide is generally used as an antifreeze compound in ice cream (Naessens et al. 2005). The dextran is flavorless, fragrance-free, and non-toxic. It is well-thought-out to have many benefits over other stabilizers for ice cream. This cryoprotectant is generally prepared by blending 2 to 4 % dextran with low viscosity (Bhavani et al. 2010).

### **Confectionery**

Dextran is used in confectioneries to maintain flavor, viscosity, humidity, sugar crystallization inhibition, and gelling agent in the gum and jelly candies (Maina et al. 2011). It is also applicable in flavor extracts, icing, dairy products, and carbonated drinks.

### **Frozen-Foods**

The advantageous features of dextran to normalize the frozen-food, air-dried and vacuum allow dextran in cheese, vegetables, meat, and fish products. Dextran coating might prevent any chemical reaction, and chemical oxidation that occurs in the food, and also it will preserve the food's color and flavor. Nowadays, due to increasing interest in fast food consumption, the frozen food industry is developing significantly with dextran as it can conserve the food texture, flavor and stimulate the odor (Bhavani et al. 2010).

### **Fermented Milk Products**

In-situ EPS production can modify the yogurt texture and yogurt-like other fermented foodstuffs made with milk by fermentation process with LAB (Madhavan Nampootheri et al. 2012). The water-binding ability of EPS obtained by LAB, especially dextran, has adversely influenced the rheology of acidified milk gels along with apparent creamy texture, thickness, and decreased syneresis (Mende et al. 2013). Therefore, the industrially employed texturizers, namely  $\beta$ -glucan, guar gum, pectin, carrageenan, and xanthan, may be replaced by dextran.

### **Prebiotics**

There has been a significant interest in using prebiotics as dietary supplements in recent years to modulate the colonic microbiota composition to provide the host with medical benefits (Saad et al., 2013). The defense against the threat of many diseases, namely bowel cancer, diarrhea, obesity, cholesterolemia, coronary heart disease, osteoporosis, inflammatory bowel disease, and type 2 diabetes, has also been associated with prebiotic-containing foods. In the human colon, *in vitro* studies were carried out. The fermentation process showing prebiotic behavior, dextran, and oligosaccharides derived from dextran was also believed to improve the significant portion of

Bifidobacterium species (Olano-Martin et al. 2000). The reports also claim that a low molecular mass dextran comprising alpha-(1, 2)-branched bonds acts as a prebiotic with a discerning effect on the gut bacteria (Sarhini et al. 2013). Recently, dextrans from *Lactobacillus plantarum* DM5 (Das et al. 2014) and *Weissella cibaria* JAG8 (Rao et al. 2013) exhibited excellent prebiotic prospects with very low intestinal digestibility and consistent probiotic stimulus. This dextran triggered microbial growth, such as *Lactobacillus sp* and *Bifidobacterium sp*.

### **Reduced-Fat Cheese**

There are several functional and textural deficiencies in reducing fat in cheese. In reduced-fat cheese, the high casein content provides a rubbery and robust body and texture. For several reasons, dextran is a suitable applicant for reducing fats in cheese. Dextran can bind and retain water to the fat-free mass and enhance moisture (Awad et al. 2005).

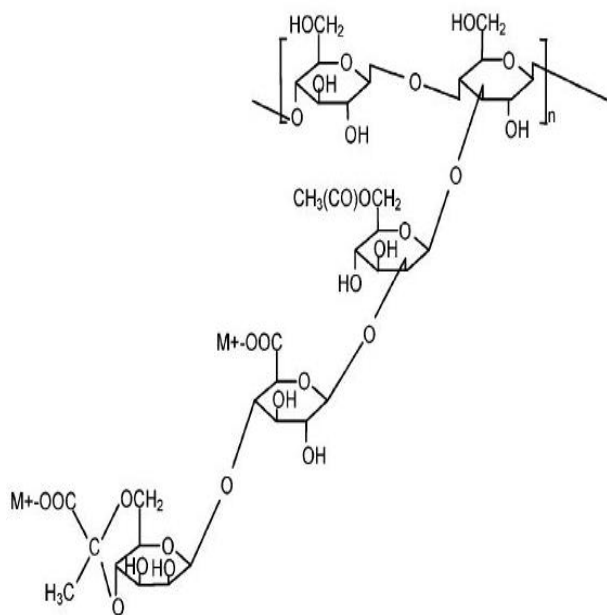
### **Protein: Dextran Conjugates**

Because of the functional properties of proteins, e.g., gelling, emulsifying, frothing, and solubility, they are extensively applicable in food products such as ice creams, mayonnaise, curd, and drinks (Oliver et al. 2006, Zhang et al. 2012). By recombining proteins and polysaccharides by Maillard's reaction, the efficient characteristics of proteins can be enhanced (Spotti et al. 2014). Maillard's products enrich bread, cereals, cakes, meat, coffee, and cocoa beans (Martins et al. 2000). The chemical and physical characteristics of proteins, such as thermal strength, antioxidant, and emulsification activity, have been improved dramatically by dextran-conjugated proteins (Zhu et al. 2010). Improvement in the efficient qualities of different proteins was studied after recombination with dextrans, which includes lysozyme, ovalbumin (Chen et al. 2014), soy protein (Zhu et al. 2010), peanut protein (Liu et al. 2012), and whey protein (Spotti et al. 2014).

### **Xanthan**

The second most commercialized natural microbial polysaccharide is xanthan, just next to dextran, and is a significant industrial biopolymer. It is a lengthy-chain polysaccharide with D-glucuronic acid, D-mannose, and D-glucose as building blocks (where one sugar residue is acetylated and the other sugar

residue in having pyruvate) with a high number of trisaccharide side chains at a molecular ratio of 3:3:2 (Fig. 2) (Bylaite et al. 2005). It was founded in 1963 at The National Center for Agricultural Utilization Research of the United States Department of Agriculture (USDA) (Margaritis 1978). The xanthan gum produced by *Xanthomonas campestris* NRRL B-1459 has been thoroughly researched due to its advantages to supplement other recognized synthetic and natural water-soluble gums. The considerable commercial manufacture of xanthan gum was initiated in early 1964. Xanthan gum has been thoroughly tested for food and pharmaceutical use toxicity and safety features. Naturally, xanthan is non-toxic and never prevents growth. Xanthan will not cause any eye or skin irritation, and also it has non-sensitizing nature.



**Figure 2.** Chemical structure of xanthan gum.

Reprinted with permission from (Bylaite et al. 2005). Copyright @ American Chemical Society

USFDA-(United States Food and Drug Administration) approved xanthan to be applicable as a food added substance without any restrictions (Kennedy et al. 1984). This polysaccharide is highly water-soluble and stable in acidic and alkaline conditions. It is highly durable in the presence of salts and is resistant to enzymes. Because of these qualities, xanthan gum has become one of the foremost polysaccharides used in the food processing sector.

**Table 3.** Applications and functions of Xanthan gum in food processing industries (Palaniraj et al. 2011)

Application	Function
<b>Bakery</b>	Connects water and enhance texture
<b>Dairy products</b>	Inhibits syneresis, stabilizes emulsions, strengthens and improves flavour release, offers optimal viscosity, long term stability
<b>Beverages</b>	Suspends fruit pulp, enhances mouth feel, maintain the suspension for texture and appearance
<b>Sauces, gravies, and dressings</b>	Offers excellent thermal constancy, inhibits divider, offers easy pourability and great hold, suspends
<b>Syrup toppings and seasonings</b>	Provides pseudoplastic flow properties, the appearance of dense and appetizing products
<b>Relish</b>	It keeps the relish and liquor evenly dispersed, enhances the exhausting weight
<b>Pet food</b>	Stabilize insoluble materials in liquid milk substitute

**Bakery**

The xanthan gum is commonly used as a suspending and condensing agent for chocolates and fruit pulp. Based on toxicology tests, the xanthan gum has been permitted by USFDA for use in human foodstuff. Most of the food requires a distinct texture, appearance, thickness, and water-resistant qualities. Xanthan gum can enhance all of the properties of food and regulate the rheology of the final foodstuff. The application and roles of xanthan gum in food industries are listed in Table 3

(Palaniraj et al. 2011) and described below. Xanthan gum is mainly employed in the bakery industry to significantly raise water retention during baking, thereby prolonging the lifespan of bakery products and refrigerated dough. Xanthan gum might be used instead of eggs in certain types of bread. Simultaneously, it could lower the egg content without influencing the texture and taste of the product. It is also frequently used to cover the exclusion of the said polymers in gluten-free products. It is commonly blended with hydroxypropyl methylcellulose (HPMC) in this circumstance. Xanthan gum enhances mass, texture, baked goods with reduced calories, and bread with no gluten. Application of xanthan gum to the fruit pie fillings and hot or cold-processed bakery stimulates the levels of texture and flavor release. Xanthan gum frequently provides procedure persistence to batters for muffins, bread mixes, biscuits, and cakes for softness, air implementation, and retention. Freeze-thaw stability, prolonged shelf stability, and syneresis control are the added benefits of fruit and cream fillings .

#### ***Dairy products***

Xanthan gum can be utilized in a combination of locust bean gum, guar gum, or both, like ice cream stabilizers, sorbet, and milk chocolate. Xanthan gum, methylcellulose, and carboxymethylcellulose works well in frozen dairy products and are suited well to yogurts produced by acidification combined with acidification carboxymethylcellulose. The same combinations are used in pudding, acidified milk creams, and others. The locust bean gum, xanthan, and guar mixture strengthen and improve flavor release in cheese spread. This economical mixing offers improved processing heat transfer, long-term stability, optimal viscosity, better flavor releases, protection from ice crystal control, and heat shock (Rosalam et al. 2006). The blend of LBG, guar, and xanthan is crucial to cream cheese slice ability, flavor release, and firm body. Xanthan gum thickens dressings such as “cottage cheese” and provides substantial syneresis control. Finally, the consistency of acid creams is improved by xanthan gum, which reduces syneresis.

#### ***Beverages***

Xanthan is used to give body to the material of beverages and squeezes. When these beverages are prepared with fruit pulp, the addition of xanthan

supports maintaining the suspension, resulting in the product right in texture and appearance. Xanthan has an excellent contribution to satisfying mouthfeel, quick and absolute solubility at low pH with an outstanding suspension of the insoluble solution, and suitability with nearly all constituents.

#### ***Sauces, gravies, and dressings***

In sauce and gravies, high viscosity at both neutral and acidic pH is obtained with the low concentrations of xanthan gum. Remarkably consistency is also maintained and is stable with the various long-term storage conditions to change the temperature. Such gravies and sauces stick to warm foods and contain excellent taste, configuration, and texture release. Almost all foods are accompanied by savory sauces and dressings that give the product a “personal touch.” Xanthan gum alone or in blend with propylene glycol alginate or pectin is widely used to provide a clean mouthfeel in salad dressings. Xanthan gum offers freeze-thaw, texture, and good body stability as a limited substitution for starch inconsistent and lowered calorie spoonable salad dressing and enhanced eating sensory experience and flavor release .

#### ***Syrups, toppings, and seasonings***

The outstanding properties of xanthan gum-containing solutions make it possible to use them in condiments, syrups, toppings, and sauces. Buttercreams and xanthan gum-containing chocolate coatings have astonishing consistency and flow characteristics due to their high resting viscosity. The viscosity gives ice cream and baked goods the appearance of dense and appetizing products . Xanthan gum is an outstanding thickening for these products due to its high constancy in acidic media. It provides pseudoplastic flow properties. The high viscosity at rest prevents seasonings and sauces from penetrating buns, giving customers more aesthetic and attractive foods. Frozen non-dairy whipped topping concentrates have elevated overrun, a healthy texture, and excellent stability of freeze-thaw.

#### ***Relish***

In the relish, the xanthan gum enhances the exhausting weight and effectively removes the loss of liquor all over handling. Xanthan gum maintains the seasoning, and the liquor is evenly dispersed



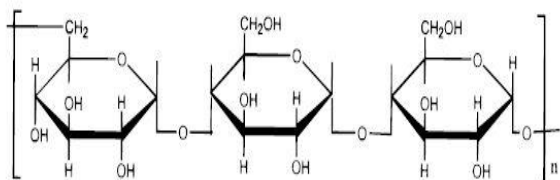
throughout the filling and stops spreading in portion package.

### **Pet food**

With LBG and guar gum, xanthan produces a uniform gel product (for semi-damp pet foods or blood cuts). Xanthan gum is utilized to soothe insoluble materials in liquid milk substitute for piglets and calves. It is often employed to formulate pet food based on canned gravy in a combination of guar gum and LBG as a preservative and binder.

### **Pullulan**

Pullulan is a neutral EPS developed in sugar and starch cultures by *Aureobasidium pullulans* (Karim et al. 2009, Cheng et al. 2010, Wu et al. 2012, Xiao et al. 2012, Xiao et al. 2012). It is a linear combined linkage comprising primarily of recurring entities of maltotriose connected by  $\alpha$ -(1,6) bonds (Fig. 3) (Donabedian et al. 1998).



**Figure 3.** Chemical structure of pullulan.

Reprinted with permission from (Donabedian et al. 1998). Copyright @ American Chemical Society

Structural stability and increased solubility benefit from the consistent recurrence of  $\alpha$ -(1, 4) and  $\alpha$ -(1, 6) bonds (Gniewosz et al. 2008, Wu et al. 2009, Jiang 2010, Göksungur et al. 2011). EPS are commonly employed in food products, often for technical purposes, for instance, stabilizing emulsions by procedure aids, providing the natural structure needed for packaging or supply. They are often employed to increase the product's 'consuming consistency' (Tiwari et al. 2021). The pullulan contains a small number of calories and is handled in humans and rats as dietary fiber (De Godoy et al. 2013). It is the result of its tolerance to mammalian amylases. The investigations show the use of nutritional pullulan as a prebiotic to encourage beneficial *Bifidobacteria* (Kycia et al. 2020). Pullulan solutions are similar to gum Arabic with relatively low viscosity. Pullulan may also be

implemented to replace starch in solid and liquid food, introducing the qualities usually obtained from starch to food such as consistency, density, and retainment of moisture pullulan could also be used in pasta dishes or bakery items as a partial starch substitute. Pullulan increases food shelf life as it is not a simply digested source of carbon for fungi, molds, and bacteria responsible for food decay.

In water preservation, pullulan is better than starch, therefore delaying food decay by dehydrating themselves (Zhang et al. 2021). Pullulan was reported to prevent fungal growth in food (Yuen 1974, Farris et al. 2014). Pullulan's suspension qualities were analyzed (Ajalloueiian et al. 2022). Pullulan could be used in drinks and sauces as a low-viscosity filler. It could also be used to balance the mayonnaise's consistency and texture. Heating, pH changes, and most metallic ions, including sodium chloride, will not affect pullulan's viscosity. Both pullulan and pullulan derivatives possess adherent properties (Leathers 2003). Pullulan could be used in food pastes both as a stabilizer and binder; it could also attach nuts to cookies. As a binding material, pullulan can also be used for tobacco (Singh et al. 2012), coat seed, and crop fertilizer (Oğuzhan et al. 2013). The Pullulan films are transparent, have high mechanical strength, and are incredibly oxygen-impermeable. These films are prepared by dehydrating the pullulan's suspension (5-10%) on a flat cover. It could be as subtle as 5-60 mm. (Yuen 1974). The films which are not derivatives are instantly dispersed as edible food coatings in water, hence containing the property of meltdown in the mouth (Prameela et al. 2018). Pullulan films' oxygen tolerance is ideal for preserving easily oxidized vitamins and fats as packaging substances for dry foods, namely noodles, nuts, confectionery, meats, and vegetables. Pullulans could also be employed in complex with polyethylene glycol or supplemented with rice protein (Trinetta et al. 2016). The pullulan may be precisely applied as a shielding glaze to foods. Pullulan replaced by cholesterol or fatty acid could be applied to preserve fatty mixtures (Bercea et al. 2019). The usage of pullulan as a gradually processed carbohydrate and its implementation within food products, particularly drinks and nutritional supplements, was reported by Wolf (2005). As human enzymes progressively transform pullulan into glucose, pullulan is stated as a

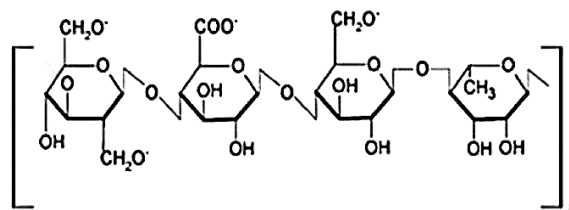
progressively consumed carbohydrate, which results in a progressive increase in human blood sugar levels. Pullulan may be added to dietary snack foods intended for people with diabetes. Pullulan is also useful for patients with decreased tolerance to glucose. Pullulan is used in frozen foods.

It improves the lifespan of ice cream, increases organoleptic characteristics, reduces the growth of crystals of ice and lactose, and improves meltdown resistance (Jeremiah 2019). Maltotriose-rich syrups are typically purified by cation exchange chromatography from maltose syrup. The maltotriose syrup can be prepared by compressing pullulan using the pullulanase enzyme.

The syrup has numerous outstanding qualities, such as less depression of the freezing point, holding in moisture, minor sugariness, preventing starch retrogradation in foodstuffs and a smaller amount of color formation in comparison to maltose syrups, glucose or sucrose syrups, firm heat constancy, high fermentability, the low viscosity of the solution and preferring smooth forms. These characteristics are helpful in the food field. In a batch method, maltotriose syrup was made by pullulan by employing a solvable and immobilized pullulan (Singh et al. 2010). A continuous benchtop scale method for pullulan hydrolysis using pullulanase, which is covalently immobilized in a packed bed fermenter, has also been developed (Singh et al. 2011).

### Gellan

Gellan is often employed in the food processing industry as a gelling agent and is the newest biopolymer available in the market. It is a linear anionic polymer with repeating tetrasaccharide units comprising two β-D-glucose residues, one of β-D-glucuronic acid and one of α-L-rhamnose (Fig. 4) with a 2:1:1 ratio (Srisuk et al. 2018). Jansson et al. (1983) first suggested the structure of gellan, which was then suggested by (O'Neill et al. 1983). The native polysaccharides present L-glycerides at O-2 from the third residue of the glucose moiety attached to the tetrasaccharide unit and one acetyl group at O-6 from the same residue in at least many glucose units (Okiror et al. 2012).



**Figure 4.** Chemical structure of gellan gum. Reprinted with permission from (Srisuk et al. 2018). Copyright @ American Chemical Society

Industrially, gellan gum is employed in numerous food applications owing to its distinctive and creative characteristics (García et al. 2018). Within these broad categories, some particular gellan gum applications are discussed in greater detail (Zhang et al. 2020) (Table 4).

**Table 4.** Food applications of Gellan gum (Zhang et al. 2020)

Application	Function
<b>Water-based gels</b>	Gels for dessert, aspics
<b>Jams and jellies</b>	Agent for glazing, bakery fillings, and jellies
<b>Dairy products</b>	Yogurt, ice cream, milkshakes, flavored milk, and cheese
<b>Beverages</b>	Fruit juice, plant protein-based drinks, alcoholic drinks, and milk-based drinks
<b>Confectionery</b>	Jelly candies, marshmallows, and high stringy candies
<b>Fruit preparation</b>	Yogurt fruit desserts, processed fruits
<b>Elderly food</b>	Pudding, a mousse for the elderly with the perfect texture
<b>Encapsulation</b>	Capsules, coating

### Water-based gels

Gellan gum is the most popular commercially available source of water-based gels, which includes dessert gels, jelly drinks, and Asian foods:

### ***Dessert or sweet course gels***

Low-acyl (LA) gellan gums create a robust and fragrant texture with outstanding clarity and thermal stability in the dessert gels. Since gellan gum is remarkably effective in making gels, the usage level is deficient, the standard rate of use ranging from 0.15 to 0.35% for dessert gels. Compared to other gums, gellan gum also offers a solid flavor release (Morris 1994, Costell et al. 2000).

However, the low-acyl (LA) gels' brittle texture is not the characteristic of popular dessert gels. Hence, LA gellan gum is frequently mixed with other gelling agents to have smoother, more elastic textures. A commercially available combination of LA gellan gum and xanthan gum with LBG is intended for a dessert gel texture (Sworn 2021). The latest commercial exploitation of refined, high-acyl (HA) gellan gum often makes it much easier to use LA and HA gellan gum blends to produce different textures (Zia et al. 2018). The resulting product's constituent's declaration is clarified since both gum types are still considered gellan gum. The HA and LA gellan gum ratio of 80 and 20 %, respectively, results in a gel quality same as gelatin dessert gel. For most gums used in dessert gels, exposure to high temperatures and acid restricts the group size and the decontamination process. However, the exceptional heat and acid stability of gellan gum allow for larger group sizes and more versatility under the decontamination process. For instance, septic fruit may be added to the cup before filling with the gel. The decontamination process may be lengthened to such an extent the fruit is wholly disinfected in the packed cup. The acid strength of gellan gum also enables the formation of dessert gels at a lower pH to boost the gels' flavoring effects (Jindal et al. 2018). In Asia, multi-layer RTE dessert gels (ready-to-eat) are standard (Diantom 2016). Various colors, textures, and flavors can be found in multiple layers. Since gellan gum has the property to melt at high temperatures, it is possible to pour hot gum solutions on the gelled layer of gellan gum, devoid of its melting. Gellan gum could also be employed in a transparent gel matrix to create heat-stable dyed beads or formed new trends that could be utilized as inclusions (Tavassoli-Kafrani et al. 2016).

### ***Jelly Drinks***

Jelly drinks are made with the same process used for dessert gels (Sworn et al. 2021). However, the gelling agents of a lower level are employed to produce an incredibly soft gel. Depending on how they will be drunk, there are various styles and textures of jelly drinks. Some jellies are smoothly adequate to be sucked using a straw for drinking. At the same time, some jellies would squeeze and push out of a sack. Jelly drinks are used simply for their fascinating textures in many Asian countries. Gellan gum jelly drinks are designed to offer enhanced nutritional or nutraceutical benefits. An instance of such a commodity is sports gels. Usually, they are packaged for use during exercise in pouches, which can be tear-off easily. The gelled substances give water and supplements without spilling, and the juicy gel pieces slip through the pharynx, devoid of leaving behind a tacky layer. LA gellan gum is usually selected in these applications because it is easy to squeeze and split the brittle gels. When split, the gels exude water rapidly, improving the release of flavor and increasing the gel's lubricity (Sworn et al. 2021). Typical levels of gellan gum use differ from 0.05 percent to 0.1 percent. By adding other gums containing HA gellan gum, jelly drinks with distinct qualities can be made (Leone et al. 2020).

### ***Asian foods***

Water-based gels are predominant in several Asian countries (Leone et al. 2020). In Japan, mitsumame prepared with tightly gelled cubes is a popular dessert. Another typical water-based jelly popular in Asian countries is Tokoroten, a transparent jelly noodle. These items were usually prepared by agar-agar, but the brittle and robust consistency of LA gellan gum is ideally suited for these gels. Gellan gum is also used in Asia to mimic the quality of such typical foodstuffs, like bird's nest soup. However, due to its small availability, it is costly. For the affordable imitation bird's nest, gellan gum is also used. LA gellan gives a subtle, flexible texture and offers heat strength for pasteurizing or retorting these materials. (Morris et al. 2012)

### ***Bakeshop***

Gellan gum is utilized almost as commonly in industrial bakery applications as in water gels. In the bakery section, several applications have been reported.

### ***Glazes, frostings, and icing***

Undissolved powdered sugar is the bulk material of glazes, frostings, and icings. Stabilizers are only successful for the processed sugar syrup that sticks together with the sugar elements. Since the total soluble in the syrup are often sugar, this system with gellan gum could be tricky. Gellan gum ought to establish a network or gel to be successful. However, the high sucrose level hinders the cross-linking of calcium. The trick to successfully utilizing gellan gum in these approaches is to produce a sodium-crosslinked gel. No network can be created without any sodium ions. More amount of sodium diminishes the web, however. Usually, sodium regulation is accomplished using sodium citrate, widely used as a hydration aid and sequestrant. The optimal sodium citrate level relies on the quantity of water in the solution (Kirchmajer et al. 2014). However, no more than 0.1 percent sodium citrate should be present in the saturated syrup. The gel network is set at about 37°C. The sucrose gel is thixotropic, so there is no issue with shearing through the specified stage. However, there is a rise in the icing viscosity at the fixed temperature, so it is beneficial to add the icing until this viscosity grows for glazes and flat icing. It is better for frostings to shear through the set stage.

### ***Bakery fillings: the key ingredients of bakery***

While discussing gellan gum for utilizing the key elements, i.e., bakery filling, it is pleasant to address bakery fillings because of reduced-solids, medium-solids, and high-solids fillings. Fillings with reduced solids contain up to 45 percent soluble solids, fillers with medium solids have 45-65 percent solids, and fillings with high solids have more than 65 percent soluble solids.

### ***Binding agents***

Gellan gum is an efficient binding agent and filmmaker. Binding is incredibly essential for manufacturers of nutritious bars and high protein bars. Usually, these products comprise protein nuggets, mainly joined through a corn syrup and stabilizer mixture. The bar can become soggy if the binding agent has far more moistness. The critical system must also be short and non-sticky in texture. Since it could directly be hydrous in corn syrup or glycerin, LA gellan gum is widely used in dietary bars (Zhang et al. 2021).

### ***Bakery mixes***

Gellan gum is beneficial for dry mixes in the bakery. Contrasting with other gums, LA gellan gum is not easily hydrated in cold water in such products. Utilizing LA gellan gum in a baker's shop doesn't improve the batter's viscosity because the gum doesn't hydrate instantly. Gellan gum usually hydrates in the oven when baking. Hence, the final baked products improve moisture retention and extend shelf life. Gellan gum primarily utilizes dry mixes created to make dense batters, such as brownies, where the batter's distribution would be stopped by excessive viscosity in a baking pan. Gellan gum's compositional effects are developed at low use levels, usually varying from 0.08 percent to 1.0 percent gum (Sworn et al. 2021).

### ***Fermented milk products or dairy foods***

Fermented dairy food is prepared by milk fermentation. Yogurts, condensed milk, and cheeses are essential products. Gelatin is widely used to alleviate many of such items. However, it is not suitable for consumers after vegan, Kosher, or Halal diets. Two methods can generate yogurts: (1) cup set and (2) agitated. In an agitated yogurt, LA and HA gellan gums may be utilized, but only HA gellan gum is required to prepare the yogurts of the cup-set type. After culturing, LA gellan gum produces a clumpy surface that needs mixing to make a smooth texture.

Before homogenization and pasteurization, gellan gum is usually applied to unprocessed milk (Sworn et al. 2021). These methods will hydrate the gum, which is common in yogurt production. It is crucial to restrict the utilization of LA gellan gum to the percent of less than 0.06, or a rough appearance can occur. Until excessive graininess appears, HA gellan gum could be employed up to the percent 0.1. Gellan gum adds a light feel at these stages of use and decreases whey-off substantially. If required, pectin or starch may be applied to create a more massive form. The processing of sour cream is the same as yogurt, but butterfat is used in the fermentation. Same as yogurt, the sour cream is usually soothed by gelatin. Both LA and HA gellan gums are being utilized to stabilize the substance. LA gellan gum is being used to develop heat resilience in the sour cream; therefore, it maintains shape after adding hot foods. For the sour cream's

pseudoplastic property, HA gellan gum is used to allow the framework to reform after mixing (Degner et al. 2014).

### ***Beverages***

Ambient, ready-to-use flavored drinks are progressively emerging worldwide. Nevertheless, there is a pitfall; several beverages struggle from cloud settlement and pulp segregation during storage. Gellan gum could be employed to counteract the settling of clouds and pulp in fruit juice while offering a relaxed and energizing mouthfeel compared to other stabilizers. Gellan gum could soothe beverages at the lowest pH of 3. Gellan gum is less reactive to proteins, making it companionable to a broad range of fruit juice (Ni et al. 2021, Sworn et al. 2021).

### ***Confectionery***

In high-solids, gelled confectionaries, LA gellan gum is commercially employed. Jellies containing slight texture and adequate release of taste are made. Due to the high melting temperature, LA gellan gum is often used to enhance the melting point of confectionaries made with gelatin. The extent of gum usage depends on the appropriate structure. With 0.35 percent gum, a smooth textured jelly can be produced. However, to make firm jelly, levels of about 0.75 percent are needed. To enhance the versatility of other hydrocolloids in desserts, gellan gum may be used. It can take several days for confections made from starch to grow a demolishable texture. Adding gellan gum in a minor fraction to a starch composition reduces the time required to set the gel significantly; therefore, the gels could be demolded on the said day. The addition of gellan gum also helps gummy confections made of gelatin. Gellan gum enhanced heat stability. The candy parts don't melt together when subjected to a hot climate (Sworn et al. 2021).

### ***Fruit applications***

In specific fruit applications, particularly the preparation of low-solid jam and yogurt fruit, gellan gum is employed. Food producers are increasingly defied to produce low-sugar and high-quality food products because of increasing customer interest in nutrition and diet. It is especially true in imitation jams or spreads that can't be dependent on corn and

sugar syrups to offer form and quality to the conclusive product. The task for producers of such foods is to establish the requisite intuitive characteristics of the set, distribution, and firmness while retaining the fruit's natural tastes and pigment. Pectin has often been employed for the production process of jams and jellies. However, particular sugar and a reasonably minimal pH are needed for its gelling mechanism. Gellan gum has been utilized to deal with these main production requirements, enabling the production of low-calorie jams lacking sugar. The yogurt fruit formulations use gelling substances to offer fruit slices with thickness and suspension. HA gellan gum in this application has been found with ultimate characteristics. The powder can be applied immediately to the fruit with low calcium and protein susceptibility, heated up like starch. HA gellan gum hangs fruit with a high setting temperature at usage ranges from 0.08 percent to 1.0 percent gum, helping to make it among the highly cost-efficient soothing approaches available (Imeson 2012, Danalache et al. 2015).

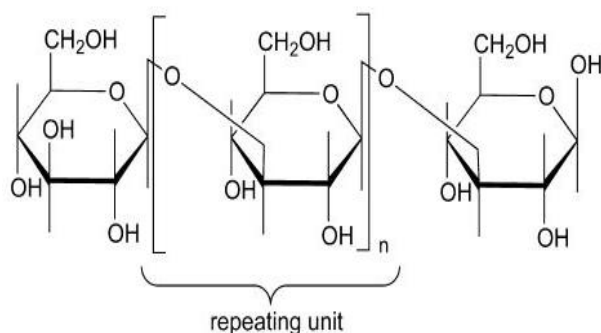
### ***Mixed applications***

Gellan gum could be used in adhesion methods, films, and sauces. For suspending herbs in fat-free salad dressings, gellan gum fluid gels are used. It is often used in complete dressings of fat marketed with aqueous layers and detaching oil. The liquid gel is also employed to disrupt thymes in the hydrous layer. In hot sauces, fluid gels have been often used to suspend chili pepper particles. Gellan gum can withstand the harsh climate without masking tastes while reducing viscosity. It is possible to dry the gellan gum solutions to create a film, which is an excellent barrier for oil but not a good barrier for moisture. Gellan gum could be utilized to coat the substrates, viz. chicken or French fries. Then it will work as a barrier for oil at the time of succeeding frying. Consequently, it reduces the considerable fat in the end product (Sworn et al. 2021).

### ***Curdlan***

The curdlan is a biological polysaccharide produced by microorganism fermentation. Curdlan is acquired by the word "curdle" to represent its gelling act at a higher temperature. The US Food and Drug Administration (FDA) affirmed it as food

added substance. It was enrolled as dietary fiber in Taiwan, Japan, and Korea (McIntosh et al. 2005). Moreover, curdlan shows potent bioactivities (Cai et al. 2017). A high molecular mass polysaccharide consists of recurrent glucose residues linked together by  $\beta$ -linkage of 1<sup>st</sup> and 3<sup>rd</sup> carbon of the hexose ring (Fig. 5) (Zhang et al. 2014). At comparatively high and low temperatures, curdlan creates a heat-set gel, or it can be created at the time of the elimination of the alkaline solution of curdlan. These heat gel qualities of the curdlan are the consequence of the change in the helical structure during the complete thermocycler (Nishinari et al. 2004). Curdlan has a broad scope of utilization in different enterprises, particularly in food. It is a component that serves as a stabilizer, gelling agent, fat replacer (FR), and thickener in numerous items.



**Figure 5.** Chemical structure of curdlan. Reprinted with permission from (Zhang et al. 2014). Copyright @ American Chemical Society

For food applications, the curdlan is employed in two classes. The top class comprises the utilization of curdlan for the improvement of food quality as a food added substance. The second class includes its utilization as a crucial requirement in freshly prepared food that possesses the novel gelling properties of curdlan. The uses of curdlan in both categories are summed up in (Table 5) (Zhang et al. 2020) and are described below.

**Application as a food added substance**

As a food added substance, a comparatively low concentration of curdlan is put into the current foodstuff to enhance, alter, and balance out the natural characteristics of the products (Zhu et al. 2021).

**Table 5.** Application of Curdlan in the food processing industry (Zhang et al. 2020)

Application	Function
Noodles	Texture modifier
Sausages, hams	Texture modifier, water holding
Kamaboko	Texture modifier
Cakes	Retention of moisture
Jellies	Gelling agent (Settled against thawing by warming and cooling)
Ice cream	Retention of shape
Cooked foods	The binding agent, enhanced wetness retaining, and product yield
Rice cake	Shape-retaining
Fabricated foods Processed tofu, noodle-shaped tofu, konjac-like gel food, heat-resistant cheese food, and thin-layered gel food	Gelling agent (Settled against thawing by warming and cooling)
Edible films	Film development
Nutritional foods	Low-energy component

The supplement of 0.2-1.0% of curdlan was used in noodles, hamburgers, hams, sausage, and kamaboko to retain water in products, improve texture, and reduce breaking intensity. In noodles, the increase in the concentration of curdlan was found with an increase in breaking intensity and the stretching during breaking. The adding of curdlan in the burgers and hams and sausage was resulted in the less cooking loss and having soft and delicious texture with the enhanced water-retaining ability of the products. The breaking intensity, as well as the

flexibility of the product, increases. Moreover, the expressible water decreases due to the enhanced water retaining ability by adding 0.5-1 % curdlan to kamaboko (Zhang et al. 2020).

#### ***Use as a vital constituent***

Curdlan is the primary ingredient and fundamental to growing new food items for this application.

#### ***Noodle-molded tofu***

In the shape of noodles, noodle-shaped tofu is a novel product processed with soy milk. Tofu is made by thickening soy milk by using coagulators viz. calcium sulfate. It is a widely devoured soybean food with a soft texture in Japan. While we considered that if tofu would process into the noodle shape, a different consistency will be acquired, the noodle shape tofu was formed by utilizing curdlan. Soy milk was treated at 60°C and added to the curdlan and coagulator. After that, to prepare a low-set gel, the starch and ice were added to the suspension, followed by homogenization and deaeration. It will result in the formation of a suspension with more thickness. The suspension was quickly expelled into the warm water using a spinneret containing several holes to prepare a high-set gel. The noodle-shaped tofu can be prepared in different forms and dimensions by changing the expelling holes (Xin et al. 2018).

#### ***Frozen noodle-shaped konjac-like gel food***

Subsequent freeze-thaw, the texture of konjac gel degenerates; therefore, it can't be employed for frozen prepared foods. Curdlan can be used to formulate freezable noodle-shaped gel with a similar texture as a konjac-like gel. The product can be formed by expelling the suspension of curdlan into the warm water with the same method used to prepare noodle-shaped tofu. This product has a versatile surface similar to konjac gel that retains even after freezing and defrosting. In frozen prepared foods, the frozen noodle-shaped konjac-like gel could be used (Zhang et al. 2020).

#### ***Tofu for freeze-drying or freezing and retorting***

Conventional tofu is occasionally utilized in prepared foodstuffs that are liable to retort, which is the root of toughening because of syneresis at the retorting procedure. Consequently, for retorting, the

tofu, which could be employed for foodstuff packed in retort pockets, was produced by new materials and methods using curdlan. Retorted Mabo-tofu (soybean curd and spiced minced meat with a Chinese dish) is an instance of prepared food using this product. The typical sauce of retorted Mabo-tofu doesn't comprise tofu due to the above explanation. Likewise, customers need to include tofu and heat before serving. Utilization of the tofu by employing curdlan could defeat this issue because the quality of the tofu is hardly altered even afterward retorting. Additionally, conventional tofu is seldom utilized in prepared food since its texture becomes like a sponge after refrigerating. Hence, tofu for freezing was made by new material and methods using curdlan. The frozen Agedashi-dofu (broiled tofu) is food processed by this product (Verma et al. 2020). Also, after freezing, the tofu holds a delicate and soft surface. Moreover, curdlan might be employed for freeze-dried tofu, which was prepared with similar procedures as the tofu for freezing was designed. The preparation is somewhat changed, and the product could be freeze-dried rather than the usual freezing. The product is reformed by using warm water, which has a smoother texture than traditional products. The traditional freeze-dried tofu consists of a layered, dense, and uneven structure found on electron micrographs. In contrast, freeze-dried tofu prepared with curdlan comprises a porous, slight, and even structure. Consequently, when soaked in warm water, the soft and smooth texture retains by the product prepared with curdlan. The freeze-dried tofu could be utilized in precooked foodstuffs (Verma et al. 2020).

#### ***Low-fat sausage***

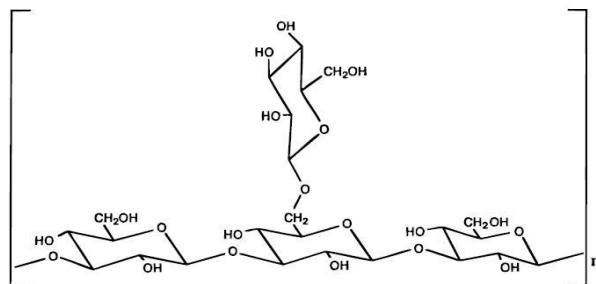
The rough-cut sausage is famous in Japan because it has a delicious, smooth, flexible surface. Nonetheless, the high-fat substance of these sausages is an issue. Therefore, the low-fat sausage was formed by eliminating the curdlan gel comprising 15% veg oil for the beef fat. The curdlan suspension and vegetable oil were emulsified, deaerated in a vacuum, and subsequently heated to prepare the curdlan gel comprising vegetable oil. The product has the same configuration and consistency as its full-fat supplement. It accomplishes a 44% decrease in fat and a 30% decrease in calories. Consequently, cholesterol is, likewise, diminished (Verma et al. 2020).

### Whipped cream without fat (simple)

The non-fat whipped cream was prepared by eliminating curdlan gel for dairy fat, an illustration of a fat replacer based on curdlan. Therefore, it is essential to add a whipping agent in the preparation, which is the same as several alternative toppings prepared from veg oil, and the gel of curdlan needs to be utterly mixed so that the component size is the same turns out sufficiently small to feel smooth in the mouth. The components of curdlan gel bring the smooth surface and retain the structure of the whipped cream as an alternative to fat milk blobs; in comparison to conventional whipped cream, a one-fourth decrease in calorie and a noteworthy reduction of fat results from the non-fat whipped cream (Nishinari et al. 2021).

### Scleroglucan

Scleroglucan is produced extracellularly by *Sclerotium*, which is a filamentous fungus. The purification of scleroglucan was completed with a natural solvent; after that, it was strained, centrifugated, dried, and then processed (Survase et al. 2007, Schmid et al. 2011). Scleroglucan is a non-ionic, balanced homoglucon comprising D-glucose as a building block. For every three significant residues, the  $\beta$ -(1-3) glucan has one  $\beta$ -(1-6) glucose residue as a side chain (Fig. 6) (Coviello et al. 1998). Although in food industries, scleroglucan is employed in food applications as a stabilizing agent, gelling agent, or as thickener. If advanced efficiency of scleroglucan might be acquired at the lowest price, at that point, it will replace xanthan in numerous foods comprising jams and preserves, ice cream parlor items, soups, water-based gels, solidified foods, dairy items, non-fat items, or in manufactured necessary food sources (Survase et al. 2007). Even though scleroglucan isn't nevertheless endorsed by foodstuff officials in the United States and Europe, San-Ei Chemical Industries, Ltd., Japan, possesses five licenses for scleroglucan to utilize a value booster for solidified foods, steamed foods, rice wafers, Japanese cakes, and pastry shop items. Scleroglucan could likewise be helpful, particularly in those food plans, including a heating cycle because it is highly stable with heat. It can again restrain syneresis, which happens at the time of preservation of prepared starch glues (Viñarta et al. 2006, Survase et al. 2007).



**Figure 6.** Chemical structure of Scleroglucan. Reprinted with permission from (Coviello et al. 1998). Copyright @ American Chemical Society

### Health benefits of EPS

There are numerous significant health benefits of EPSs such as antioxidants (Kodali et al. 2008), reducing cholesterol (Welman et al. 2003), anti-cancer activity (Liu et al. 2020), EPS also found to show antiviral as well as immunomodulatory activities (Arena et al. 2006). It has been proven that EPSs have free radical properties and antioxidant activity for scavenging. To inhibit the oxidation of vegetable oils, the EPSs with free radical scavenging activity could be employed. Kishk et al. (2007) have shown antioxidant and free radical scavenging property of EPS that has extracted by *Rhizobium meliloti* and demonstrated the competence of EPS to avoid the oxidation of lipid in sunflower oil suspensions throughout a 50-hour holding period at 60°C. Reactive oxygen species (ROS) such as nitric oxide (NO), hydroxyl (OH), and superoxide (O<sub>2</sub>) contribute to a variety of severe medical conditions, including atherosclerosis, cancer, Parkinson's disease, and rheumatoid arthritis.

### Conclusions

The microbe-derived polysaccharide family plays a crucial role in many industries and is an unavoidable part of food processing. These exopolysaccharides produced by microbes act as thickeners, stabilizers, texturizers, and as a gelling agent, improving the food's consistency, texture, mouthfeel, and flavor. It means that food-processed packages available on the market today have elevated food quality standards from ready-to-eat meals to the instant mix as a blessing to humanity in today's era. The manufacture of value-added microbial biomass biochemicals is a better alternative to harmful



chemical synthesis processes using costly, dangerous, and non-renewable raw materials. While a biopolymer can demonstrate its market potential because of its functional characteristics, it can not find its proper position until the polymer is economically produced. For any high-value biopolymer, stability in product quality and yield is essential. It can be ensured by eliminating the carryover's waste products and metabolic by-products to a large degree. Studies are currently concentrating on improving the process parameters for polysaccharides by observing the value of microbial polysaccharides.

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