Henry
Journal of Nutrition & Food Sciences

Short Review

The Applications of Alginate in Functional Food Products

Yimin Qin[1,2]*, Guofang Zhang[2] and Haihua Chen[3]

[1]*College of Material and Textile Engineering, Jiaxing University, Jiaxing 314001, Zhejiang Province, China*

[2]*State Key Laboratory of Bioactive Seaweed Substances, Qingdao Brightmoon Seaweed Group, China*

[3]*College of Food Science and Engineering, Qingdao Agricultural University, China*

Abstract

Alginate is an established food ingredient widely used in the production of functional food products. As a food ingredient, the applications of alginate are based on three main properties, i.e., thickening, gelling and film forming. This paper summarizes the main properties of alginate and its applications in a myriad of newer functional food products, from edible food jelly, restructured meat, coating for pre-packed, cut or prepared fruits and vegetables, etc. In addition, new applications are also emerging following the chemical, physical and biological modifications of alginate to yield derivatives with specialized functional properties. In this respect, the paper also summarized the application of alginate oligomer and propylene glycol alginate in the production of meat products, pasta products, drinks and many other forms of food products.

Keywords: Alginate; Biopolymer; Dietary fiber; Food ingredient; Functional food

***Corresponding author:** Yimin Qin, College of Material and Textile Engineering, Jiaxing University, Jiaxing 314001, Zhejiang Province, China, Email: yiminqin1965@126.com

Received Date: April 12, 2020

Accepted Date: April 18, 2020

Published Date: April 27, 2020

Citation: Qin Y, Zhang G, Chen H (2020) The Applications of Alginate in Functional Food Products. J Nutr Food Sci 3: 013.

Introduction

Marine biomass represents a vast amount of structurally diverse natural resources, of which, seaweeds are commercially important varieties of renewable resources that are widely used as raw materials for the extraction of bioactive materials for applications in pharmaceuticals, nutraceuticals, functional foods, biomedical materials, cosmetics, fertilizers and many other industries [1-4]. Among the many bioactive substances existing in seaweeds, alginate is a polysaccharide extracted from brown seaweeds, where it exists as a cell wall component with structural functions similar to carrageenan and agar [5,6]. As a polymeric acid, alginate is composed of 1, 4-linked α-L-guluronic acid (G) and β-D-mannuronic acid (M) residues. As can be seen in Figure 1, these two acid residues are stereochemically very different as a result of their difference at C-5. Alginate extracted from different species of seaweeds differ in G and M contents, which are present in the polymer chain as GG, MM and MG/GM blocks of various proportions, resulting in the differences in the physical properties of the respective alginate products.

As shown in Figure 2, alginate can be extracted from seaweeds through a series of steps involving dissolution of the alginic acid in seaweed biomass with an alkali solution, precipitation of sodium alginate with calcium chloride and the subsequent filtration, purification and drying operations. Since it was discovered by Stanford in 1881, alginate has been used in a wide range of industries, such as food ingredients, textile printing paste, paper coating, pharmaceuticals, wound dressings and many other novel end uses. The applications of alginate are based on three main properties. The first is its ability to thicken the resulting solution when dissolved in aqueous solutions, i.e., its ability to increase the viscosity of aqueous solutions. The second is its ability to gel when a calcium salt is added to a solution of sodium alginate in water, with no heat required to form the heat stable gel, which is different to carrageenan and agar gels where the water must be heated to about 60°C and 80°C respectively for dissolution to take place, with detrimental effect on the bioactive components involved. The third property of alginate is the ability to form films of sodium or calcium alginate and fibers of calcium alginates.

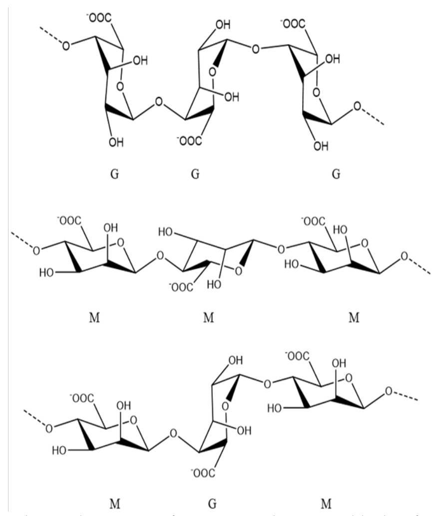

Figure 1: The chemical structure of GG/MM and GM/MG blocks of of alginic acid.

Because of the thickening, gelling and film forming properties, alginate is widely used in the food and drink industries, functioning as one of the most important food ingredient. However, in this highly competitive market, alginate must compete with other similarly important food hydrocolloids, including plant gums such as guar and locust bean, cellulose derivatives such as carboxymethyl cellulose (CMC) and methyl cellulose, and marine hydrocolloids such as carrageenan and agar. While each of these functional food ingredients have their own unique properties, the novel structural characteristics and the related functional performances make alginate and its many derivatives as a group of technically versatile, functionally diversified and commercially important functional food ingredients.

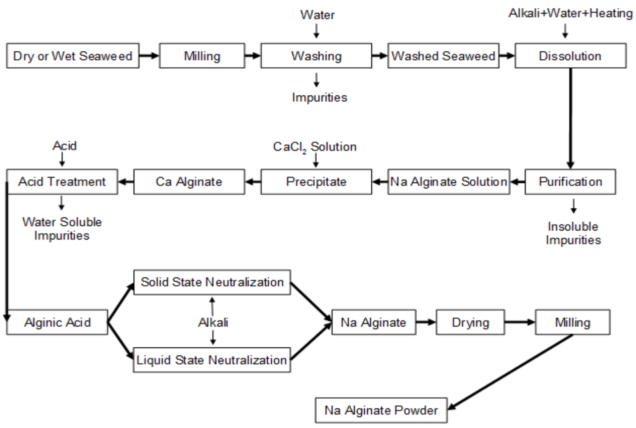

Figure 2: Process flow chart for the extraction of alginate from brown seaweeds.

Applications of Alginate in the Food in Dustry

Alginate has unique thickening, gelling, stabilizing and film forming properties that are highly valuable in the food industry. In addition, its unique structure is also related to some biological functions that are highly beneficial to human health [7,8].

Functional properties of alginate

Alginate as a thickening and stabilizing agent

As a natural water soluble polymer, alginate forms viscous solution when dissolved in water. Figure 3 shows the effect of concentration on sodium alginate solution viscosity. It is clear that the viscosities of sodium alginate solutions are higher than those made from other thickening agents, whilst at the same time, they also display a remarkable shear thinning effect, which is important in that, the shearing applied during processing can lower the viscosity of the food mixture to assist smoother flow [9].

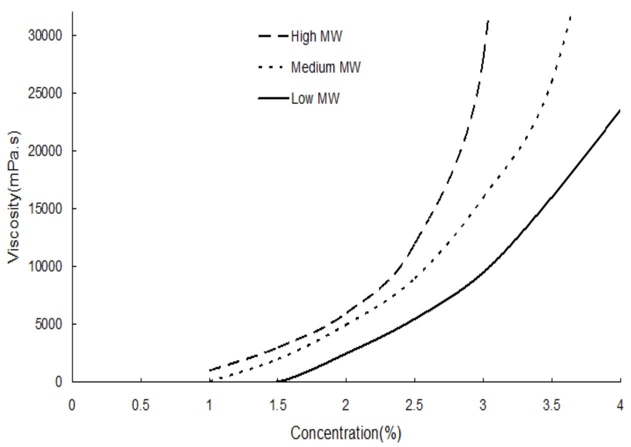

Figure 3: Effect of concentration on sodium alginate solution viscosity.

The thickening properties are commonly exploited in jams, marmalades and fruit sauces, as alginate–pectin interactions are heat-reversible and give a higher viscosity than does either individual component. Alginates are also used to thicken desserts and savoury sauces, including mayonnaise. Use of alginate on its own or in conjunction with other thickening agents has been shown to improve the acceptability of a number of low-fat processed foods. The hydrophilic nature of alginate aids retention of moisture and improves food texture, resulting in an improvement to the organoleptic qualities of the food products, thus improving consumer acceptance [10].

As a gelling agent, alginate forms stable gels at high and low temperatures and at low pH, which can be used for a number of stability applications in food processing. Routine use of alginates in bakery creams endows the cream with freeze/thaw stability and reduces separation of the solid and liquid components (syneresis). In ice cream products, alginate is often used in combination with other hydrocolloids for thickening and stabilizing functions, allowing control of the product's viscosity, increasing heat-shock resistance, reducing shrinkage and ice crystal formation, and endowing the ice cream with the desired melting characteristics.

Alginate as a gelling agent

As shown in Figure 4, when sodium alginate solution is in contact with divalent metal ions such as calcium ions, a gelled structure forms with the subsequent trapping of a large amount of water inside the polymeric network. Commercially, alginate is available at a wide range of viscosities, and therefore it has a wide range of uses as gelling agents. The gelling rates and gel strength can be controlled by the concentration of Ca^{2+} or H^+ in solution, in addition to the proportion of G blocks within the polymeric chain. As alginate forms gels at low temperatures, it is particularly useful in the restructuring of foodstuffs that may become damaged or oxidized under high temperatures, e.g. meat products, fruits and vegetables [11,12].

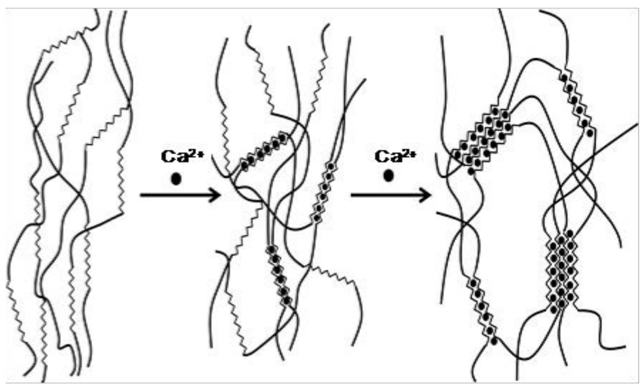

Figure 4: An illustration of the formation of cross-linked structure through the interaction of calcium ions with carboxylic acid groups.

The ability of alginate to form heat stable gel can be used to make restructured foods which produce functional foods from less aesthetically appealing produce such as cuts of meat with high fat or connective tissue content, misshapen or missized fruits, etc. By increasing the aesthetic quality of foods, restructured forms can often offer novel products that help meet customer demand. Restructured foods can be produced in any shape or size, which allows production of foodstuffs that are of a more uniform or attractive aesthetic nature. At the same time, the texture and structural properties of the foods can be controlled to produce more desirable products.

Alginate as encapsulation and immobilization agents

In the food industry, delayed release, stability, thermal protection, and suitable sensorial profile are important characteristics, which would be difficult to achieve without microencapsulation and immobilization techniques. Utilizing its gel forming capabilities, alginate based capsules can be made by spray drying, spray cooling, spray freezing, microfluidization, and other novel encapsulation technologies. These microencapsulation products have a number of applications in the food industry, including encapsulation of reactive or volatile molecules, such as acidulants, fats and flavors. Outside the food industry, these technologies have been utilized in a wide range of drug delivery applications. For example, microencapsulation of insulin-producing cells for injection into type I diabetics has been shown to be an effective treatment [13,14].

Within the food industry, alginate encapsulation and immobilization technologies are used for a variety of purposes, including food processing, food functionality and product acceptability. These immobilization technologies can enhance productivity as a result of continuous operation and reuse of the entrapped cells or enzymes. Immobilization or encapsulation technology is used to produce a wide range of bacterial metabolites, including enzymes, amino acids, organic acids (e.g. acetic acid) and alcohols.

Alginate for food coating

As a linear polymer, alginate forms clear transparent film upon dissolution in water and drying. Alginate films have excellent tensile strength and flexibility, in addition to being resistant to tearing and impermeable to oils. Once an aqueous solution is cast on the surface of foods, alginate transforms into an edible coatings, offering protective functions to the foodstuff. Owing to the current call for reduction or replacement of non-biodegradable or non-recyclable food packaging, the film forming ability of alginate has a high potential in the functional food industry. Alginate based food coatings are safe to use, easy to process and possess excellent product stability and shelf life. However, the porous nature of alginate gels makes them permeable to oxygen and water [15,16].

Absorption of heavy metal ions

As a polymeric acid, alginate has strong binding to heavy metal ions [17,18]. In a study on the binding abilities of alginate for divalent metal ions during gel formation of sodium alginate solution, Haug & Smidsrod [19] noted that the ability for alginate to bind divalent metal ions is related to the ion exchange coefficient between the divalent metal ion and the sodium ion:

K=[Metal ion concentration in the gel][Sodium ion concentration in the solution]^2/[Sodium ion concentration in the gel]^2[Metal ion concentration in solution]

After studying various metal ions, Haug & Smidsrod found that the binding abilities for alginate are in the order of:

$Pb^{2+}>Cu^{2+}>Cd^{2+}>Ba^{2+}>Sr^{2+}>Ca^{2+}>Co^{2+}=Ni^{2+}=Zn^{2+}>Mn^{2+}$

The strong binding for lead ions has been successfully utilized to develop formulations for children with high levels of lead in blood.

Applications of alginate in functional food products

As a natural plant extract, alginate has excellent biocompatibility and safety. It was granted the GRAS (Generally regarded as safe) status by the FDA in the 1970s and was included in the US Pharmacopeia as early as 1938. In 1994, the joint expert committee of WHO and FAO agreed that there is no specific requirement on the acceptable daily intake (ADI) of alginate. In 1997, the Chinese Ministry of Health granted alginate as possessing the ability to remove lead and can be used in health foods. Because of its safety and excellent functional properties, alginate has found widespread applications in functional food products.

Applications of alginate in edible food jelly

Edible food jelly is popular in many parts of the world. Traditionally, these gelled foods are made from starch of many origins, such as peas, maize, mung beans, rice, wheat, etc. There are also jelly products made from red seaweeds such as Gelidium amansii and gelatin from animal sources, using hot water to dissolve the ingredients and set the gels upon cooling. Alginate based gels are unique in that because the gels are formed through ionic cross-linking by divalent metal ions, they are heat stable and thermally irreversible, while holding a large amount of water through the hydrophilic groups in alginate. This novel property gives alginate based food gel the following properties:

1. A crispy taste with a low calory
2. The ability to lower blood pressure and cholesterol, promote gastrointestinal peristalsis and remove heavy metal ions
3. Good thermal stability, allowing it to be used in hot-pot, hot soup, stir fried dish and many other types of food

Figure 5 shows some examples of alginate based food gels. Because of their heat stability, these products can be served in a number of ways such as deserts, soaps, hot pots, etc. They can also be stir fried with other food ingredients.

Figure 5: Examples of alginate based food gels.

Applications of alginate in analog foods

Analog foods are also known as manmade foods, which are made to resemble the physical appearances and mouth tastes of foods of natural origin, especially those of rare natural sources. They are made by assembling the nutritional components found in the natural food by using chemical and physical means. Analog foods are commercially important in that common food ingredients can be made into high valued products and consumers can have the opportunity to eat speciality foods that are otherwide not available to them.

The gelling properties of alginate, in particular its thermal stable nature, make it ideal as a restructuring agent. It has been widely used to make artificial shark fin and artificial jellyfish skin. In addition, it has also been used for the production of artificial lean beef jerky and other bionic meat, artificial rice, artificial apple, artificial coffee, artificial pineapple, etc. These products are made to resemble their natural equivalents in physical appearances, mouth feel and biological functions.

A typical example is analog caviar which is commonly made by combining alginate gel with fruit-vegetable powder. Table 1 shows a recipe for the production of analog caviar and Figure 6 shows an illustration of this product [20].

Ingredients		Concentration (%)
Analog caviar preparation	Sodium alginate	1.2-1.5
	Fruit-vegetable powder	3-8
	Acidulant	0.1
	Sweetener	0.1
	Water	90-95
Coagulation solution	Calcium gluconate	5-10
	Water	90-95

Table 1: Recipe for the production of analog caviar.

Figure 6: An illustration of analog caviar.

Applications of alginate in meat products

The film forming properties of alginate can be used as sausage casing and for coating meat products. The transparent alginate film is easily formed by coating the meat products first with aqueous sodium alginate solution and then placing it in contact with aqueous calcium chloride solution. The resultant film helps prevent or reduce the loss of water and oily components. Figure 7 shows some examples of alginate coated meat products.

Figure 7: Examples of alginate coated meat products.

Using its ability to form thermally stable gel, alginate can be used to make fat replacers whereby animal fat or plant oil can be dispersed in an alginate gel matrix to prepare fat like substances that can be used in salami and similar products to produce meat products with relatively low calory whilst maintaining the traditional texture and appearances. Figure 8 illustrates the application of alginate based fat replacer.

Applications of alginate in pasta products

Sodium alginate and calcium alginate can be added into flour mixture in the production of pasta products. The addition of alginate can improve the anti-freezing and anti-aging properties, as well as create a smooth texture and reduce the rate of breakage for noodles. Figure 9 shows some examples of alginate based pasta products.

Figure 8: Applications of fat replacer in salami.

Figure 9: Examples of alginate based pasta products.

Applications of alginate in dairy products and drinks

In dairy products, alginate is used as thickening and emulsifyin agent where it can stabilize protein, emulsify fat, improve taste and protect aroma. In neutral drinks, alginate can increase product stability and prevent the separation of the various ingredients within the system. In ice cream, alginate can improve product stability against freezing and help yield delicate taste.

Alginate Derivatives

As a polymeric acid, alginate has an abundance of free hydroxyl and carboxyl groups distributed along the polymer chain backbone, which can be chemically modified to generate derivatives with new functional characteristics. The chemical reactions include oxidation, reductive-amination, sulfation, copolymerization, coupling of cyclodextrin units and many others [21]. Through functionalizing available hydroxyl and carboxyl groups, the properties such as solubility, hydrophobicity and physicochemical and biological characteristics can be modified to broaden applications [22]. When used in the food production process, these chemically modified alginate derivatives can generate new properties for the functional food products. Figure 10 shows an illustration of the many derivaties of alginate.

Oxidized alginate is an important derivative of alginate where the oxidation reaction can generate more reactive groups and a faster degradation rate [23,24]. Oxidation reaction is applied on the–OH groups at C-2 and C-3 positions of the uronic units of sodium alginate with sodium periodate, resulting in the rupture of carbon–carbon bond and the formation of two aldehyde groups in each oxidized monomeric unit, and as a result, larger rotational freedom and new reactive groups along the backbone are obtained. The degree of oxidation can be controlled by varying the concentration of the oxidant [25]. Figure 11 shows an illustration of the oxidation of sodium alginate by using sodium periodate.

Figure 10: An illustration of the derivaties of alginate.

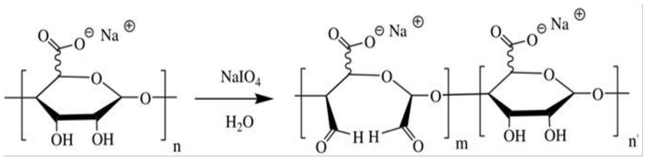

Figure 11: The oxidation of sodium alginate by using sodium periodate.

Applications of Alginate Derivatives in Functional Food Products

Applications of alginate salts in functional food products

In addition to sodium and calcium alginate, other types of alginate salts can also be used as food ingredients. A typical example is zinc alginate which can be used to deliver zinc ions. Figure 12 shows the zinc ion concentration in the contacting solution when zinc alginate is placed in contact with aqueous solutions containing different amount of protein [26].

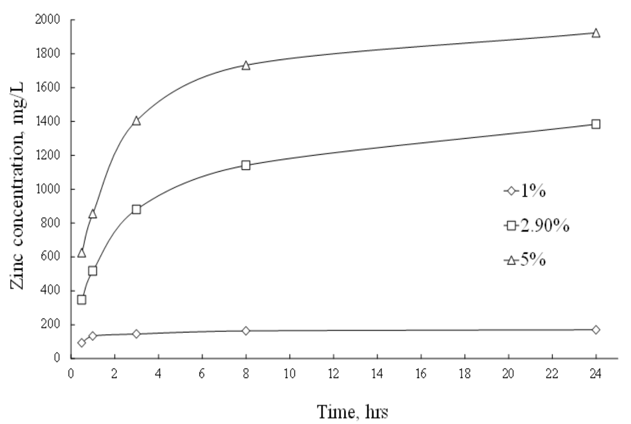

Figure 12: Zinc ion concentration in the contacting solution when zinc alginate is placed in contact with aqueous solutions containing different amount of protein.

Applications of alginate oligosaccharides in functional food products

Alginate oligosaccharides are prepared by the chemical, physical or enzymatic degradation of naturally occurring alginate with large degrees of polymerization (DP) [27]. Whilst alginates extracted from brown seaweeds usually have DPs more than 100, the DPs for oligosaccharides are normally 2-10, which offer them high solubility, good diffusion property and generally stronger bioactivities. Alginate oligosaccharides are known to possess antitumor, antioxidant and immuoregulating properties that are highly useful in the production of functional foods, neutraceuticals, cosmetic products, biomedical materials, agricultural biostimulants, etc [28-31]. In particular, they can be added into food products and drinks to enhance functional health benefits.

Applications of propylene glycol alginate in the food and drink industry

Propylene Glycol Alginate (PGA) is an esterified derivative of alginate that is widely used in the food and drink industry. PGA was developed by Kelco in 1949 [32,33]. The production process begins with the extraction of alginic acid from brown seaweeds by first removing the impurities with dilute hydrochloric acid, followed by agitating and extracting with sodium hydroxide solution or sodium carbonate solution. After the sodium alginate is purified and filtered, it is transformed into alginic acid through acidifying and precipitation. The resultant alginic acid is then esterified with propylene oxide at 70 ºC under pressure with alkali as catalyst before the reaction mass is washed with methanol, squeezed, dried and crushed to yield PGA [34].

Figure 13 shows an illustration of the conversion of alginic acid into propylene glycol alginate. Because the carboxyl group of alginic acid is replaced by propylene glycol ester, PGA is soluble in water while remaining stable in acidic environment upto pH3-4, where sodium alginate would precipitate out as alginic acid. This tolerance to acidic environment together with its strong salt resistance makes PGA highly valuable in foodstuff and beverages with strong acidity and high levels of metallic ion such as calcium, sodium, etc, where PGA is able to improve the stability of acid in foodstuff and also prevent the lay down created by calcium and other high valued metallic ions. In addition, PGA also has good lipophilicity and emulsion stability due to the propylene glycol group contained in its molecules. Because of these unique properties, PGA is particularly useful in low pH foodstuff and beverages such as lactic acid beverages, fruit juice beverage, etc. Figure 14 shows the effect of pH on the viscosity of PGA solution.

Application of PGA in juices

For fruit juices, one of the common problems during storage is that the juice can be easily stratified with clear and transparent super stratum and the thick precipitated marrow as substratum. Hydrophilic colloids are often used to improve this problem but if it markedly increases the viscosity of juice system at the same time, the mouth feel will also change. It has been found that PGA is ideally suited for the improvement of marrow stability without any side effect. The addition of 0.1% PGA can satisfy the requirement to make the juice remain stable without impairing the savor and composition of juice, while other hydrophilic colloids such as xanthan gum, carrageenan, etc, may has such adverse affects. Because of the ability of PGA to stabilize and hence increase the concentration of solids in the juice, consumers

ISSN: 2565-5779

can also expect a better mouth feel. It was also found that PGA has a stabilizing effect on the oil composition of juice, due to its excellent emulsifying property.

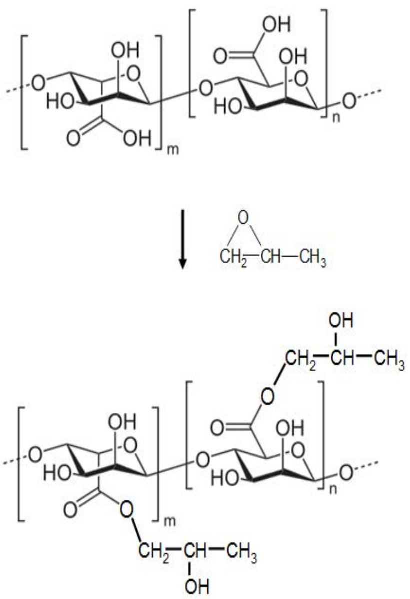

Figure 13: An illustration of the conversion of alginic acid into propylene glycol alginate.

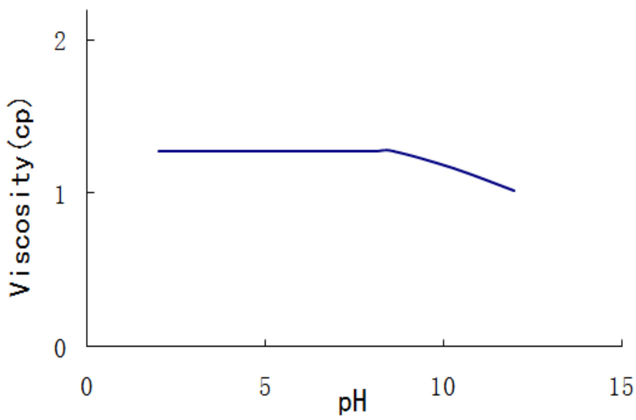

Figure 14: Effect of pH on the viscosity of PGA solution.

Application of PGA in beer

Because of the lipophilicity and hydrophilicity properties in the molecular structure, PGA has emulsifying, thickening, swelling, acid resistance and stabilizing properties, which are ideal characteristics for stabilizing agents in acid protein beverages. The beer foam stabilizer is a typical application for PGA with high esterification degree and its general dosage is 40-100mg/kg. PGA can unite with foam-producing natural protein and consolidate the wall, delay elimination of liquids from foam, and thus delay the duration of foam by 2-3 minutes and affect foam adherence to the wall. Furthermore, foam is pure white with lasting adherence to glass while the taste and storage period of beer do not change.

Application of PGA in blending type acidic milk beverage

Raw milk powder, soybean milk, lactic acid, citric acid, sugar or other sweetening agent, stabilizer, coloring agent, and other ingredients are mixed to make blending type acidic milk beverage, where the pH is adjusted to acetic isoelectric point of blow pH4.6 by lactic acid, citric acid or fruit juice, etc. While precipitation and stratification are the usual quality problems in the production and storage of acidic milk beverages, PGA has proved to be the most suitable stabilizer for this type of products, especially when it is used in combination with other acid resistant hydrocolloids such as acid-resistant CMC, xanthan gum, pectin, etc. Their total concentration is usually below 0.5%, in which PGA accounts for about 60-70%. It was found that product with compound stabilizer with PGA as main component is excellent in both stability and mouth feel and completely satisfy the quality requirement of the product of this category.

Application of PGA in yoghurt

Yoghurt is a popular milk product with a high nutritional value. It is divided into coagulation type and agitation type, with the coagulation type yoghurt directly fermented in solid state which should be sold in cold storage after fermentation. The agitation type yoghurt is fermented in large fermentation tanks and then agitated and cooled down. When juice is added, it often settles on the bottom of the coagulation type yoghurt with other fermenting stuff on the top. For both the coagulation type and agitation type yoghurts, the texture may not be dense, while the dewatering and shrink of whey make them less tasteful. Among the many stabilizing agents for yoghurt, gelatin is banned by vegetarian and the doctrine of Judaism, karaya gum is not very stable in low pH acidic milk products, while pectin hardens the product during storage. PGA has been found a more effective stabilizing agent for yoghurt, with the following advantages:

- PGA can endow yoghurt products with natural texture and mouth feel, which can be well shown even if the addition of milk is lowered;
- PGA can efficiently prevent the formation of coarse surface and make the product appeae smooth and glossy
- PGA is able to completely mix with other feedstock and can be used in any pH range, evenly dispersed into yoghurt under mild agitation
- PGA not only functions as stabilizing agent but also gives emulsifying effect to yoghurt

Application of PGA in ice cream

PGA was used as a stabilizer in ice cream as early as 1934. During the manufacturing process, it improves the dispersion of grease and fat-containing solid particles, improves the internal structure and appearance, and gives the product better mouth feel. In addition, it can also increase the dispersion stability and non-deliquescence, and prevent the creation of ice crystal of lactose in the ice cream. In practice, PGA is often used in combination with other hydrocolloids such as xanthan gum, gum cyanosis, locust bean gum, CMC, etc, to give better effects and performance-price-ratios.

Application of PGA in salad dressing

PGA is used as stabilizer and emulsifying agent in salad dressings, where it not only provides gratifying texture but also supplies emulsion stability and stable suspension of solid particles, in addition to certain thickening function. PGA is very stable at low pH and is resistant to salt. As an important ingredient of high-grade salad dressing or salad flavoring, PGA has the following advantages:

- PGA can provide salad dressing with rich and soft texture, giving emulsification effect to oil and water mixture and making salad dressing system uniform and stable;
- PGA can provide salad dressing with features similar to grease. The main reason resides in its hydrophilic and hydrophobic groups in the structure, which make it possess features similar to natural fat. PGA is the only water-soluble colloid with hydrophobic groups, making it an excellent emulsifying agent in salad dressing;
- PGA can increase the viscosity of finished goods. It can make up for the loss of viscosity due to the reduction of fat content in low fat salad dressing;

Applications of PGA in bakery products

In a recent development, Liu et al [35] added PGA into dough and studied the effect of PGA on the rheology of the dough and the characteristics of the resultant bread. It was found that the addition of PGA can considerably improve the farinose quality and elasticity, and enhance the dough stability and extensibility. After analyzing the quality of the bread, it was further found that the addition of PGA can increase the specific volume of bread and significantly improve the elasticity, reduce the hardness, improve the taste and sensory score of the bread. The optimum addition was found to be 0.2%-0.3%. In another study, it was found that the best performance was achieved when the viscosity of PGA is within 300-400mPa·S for a 1% aqueous solution [36]. Figure 15 shows a comparison of breads made with and without PGA.

Figure 15: A comparison of breads made with and without PGA. Left: without PGA; Right: with 0.2% PGA.

PGA can also be added into cake to improve its texture and extend shelf life. Table 2 shows a recipe for a cake containing PGA. Once the mixture is prepared and added into the mould, the oven temperature is raised to 180°C for 10 min before rising to 200°C for another 10 min [20]. As shown in Figure 16, the PGA containing cake offers a better bulky texture than the control sample. It has been shown that the addition of 0.1%-0.3% PGA can help emulsify the egg mixture and stabilize the batter. In addition, PGA can increase the cake volume to make the cake puffy and elastic. The internal texture is also much more even and fine.

Applications of PGA in pasta products

The common problems with pasta products are poor chewiness, high broken rate, muddy soup, etc. It has been found that the addition of PGA can reduce the loss of dry matter during cooking and increase hardness, chewiness, spingness and gumminess. The excellent emulsifying properties of PGA can promote the formation of stable structure for the starch and mitigate its deterioration. In addition, through its interaction with the protein molecules in the flour, a stable network structure is formed within the pasta product, resulting in improved texture. Table 3 shows the effect of PGA concentration on noodle quality [37].

Step	Procedure	Ingredient	Proportion relative to flour
1	Egg mixture	Egg	175-200%
		Sugar	80-100%
		PGA	0.1-0.3%
		Salt	1-1.5%
2	Flour mixture	Flour	100%
		Baking powder	0.5-1%
3	Addition of water and oil	Water	35-45%
		Vegetable oil	35-45%
4	Baking		

Table 2: Recipe of a cake containing PGA.

Figure 16: A comparison of cakes with and without PGA. Left: without PGA; Right: with PGA.

Test	Amount of PGA added					
	0%	0.1%	0.2%	0.3%	0.4%	0.5%
Hardness, N	6.55	6.53	6.78	7.48	7.95	7.91
Springness, mm	0.63	0.64	0.64	0.62	0.63	0.63
Chewiness, mJ	2.89	3.18	3.30	3.53	3.93	3.51
Gumminess, N	4.47	4.67	4.97	5.43	5.81	5.25

Table 3: Effect of PGA concentration on noodle quality.

Summary

Alginate has been used as a functional food ingredient for a long time and the many functional benefits have been confirmed in its diversified applications where the thickening, gelling and film forming properties are highly useful. In recent years, many new functional food products are emerging partly in respone to the health problems facing consumers in the modern time. In this respect, edible gels based on alginate have emerged as a food product with anti-obesity properties, among other benefits such as de-toxicating heavy metal ions and improving disgestive systems. The many derivatives of alginate, in particular propylene glycol alginate and alginate oligosaccharides are also increasingly used in food and drink product ranging from traditional meat and pasta products, to health promoting products such as neutraceuticals.

Reference

1. Das D (2015) Algal Bio-refinery: An Integrated Approach. New York: Springer.
2. Glicksman M (1987) Utilization of seaweed hydrocolloids in the food industry. Hydrobiologia 151: 1-47.

3. Zhang C, Li X, Kim SK (2012) Application of marine biomaterials for nutraceuticals and functional foods. Food Sci Biotechnol 21: 625-631

4. Holdt S L, Kraan S (2011) Bioactive compounds in seaweed: Functional food applications and legislation. J Appl Phycol 23: 543-597

5. Brownlee IA, Allen A, Pearson JP, Dettmar PW, Havler ME (2005) Alginate as a source of dietary fiber. Critical Reviews in Food Science and Nutrition 45: 497-510.

6. Dettmar PW, Strugala V, Richardson JC (2011) The key role alginates play in health. Food Hydrocolloids 25: 263-266.

7. Paxman JR, Richardson JC, Dettmar PW, Corfe BM (2008) Alginate reduces the increased uptake of cholesterol and glucose in overweight male subjects: a pilot study. Nutrition Research 28: 501-505.

8. Paxman JR, Richardson JC, Dettmar PW, Corfe BM (2008) Daily ingestion of alginate reduces energy intake in free-living subjects. Appetite 51: 713-719.

9. Larsen BE, Bjørnstad J, Pettersen EO, Hanne Hjorth Tønnesen, Jan Egil Melvik (2015) Rheological characterization of an injectable alginate gel system. BMC Biotechnology 15: 29-40.

10. Fu S, Thacker A, Sperger D M, Boni RL, Buckner IS (2011) Relevance of rheological properties of sodium alginate in solution to calcium alginate gel properties. AAPS PharmSciTech 12: 453-460.

11. Hampson FC, Farndale A, Strugala V, SykesJ, Jolliffe IG (2005) Alginate rafts and their characterisation. International Journal of PharPharmaceutics 294: 137-147.

12. Ohta A, Taguchi A, Takizawa T, Adachi T, Kimura S (1997) The alginate reduce the postprandial glycaemic response by forming a gel with dietary calcium in the stomach of the rat. International Journal for Vitamin and Nutrition Research 67: 55-61.

13. Datta S, Christena LR, Rajaram YRS (2013) Enzyme immobilization: an overview on techniques and support materials. Biotech 3: 1-9.

14. Dordevic V, Balanc B, Belscak-Cvitanovic A, Steva Levcć, Kata Trifkovic (2015) Trends in encapsulation technologies for delivery of food bioactive compounds. Food Eng Rev 7: 452-490.

15. Campos CA, Gerschenson LN, Flores SK (2011) Development of edible films and coatings with antimicrobial activity. Food Bioprocess Technol 4: 849-875.

16. Quirós-Sauceda AE, Ayala-Zavala F, Olivas GI, González-Aguilar GA (2014) Edible coatings as encapsulating matrices for bioactive compounds: A review. J Food Sci Technol 51: 1674-1685.

17. Smidsrod O, Draget KI (1996) Chemistry and physical properties of alginates. Carbohydrates in Europe 14: 6-13.

18. Savchenko OV, Sgrebneva MN, Kiselev VI, Khotimchenko YS (2015) Lead removal in rats using calcium alginate. Environ Sci Pollut Res 22: 293-304.

19. Haug A, Smidsrod O (1965) Effect of divalent ions on solution property. Acta Chemica Scandinavica 19: 341-351.

20. Qin Y (2019) Marine Functional Food Ingredients: Functions and Applications of Polysaccharides from Brown Seaweeds. Beijing: China Light Industry Press.

21. Yang JS, Xie YJ, He W (2011) Research progress on chemical modification of alginate: A review. Carbohydrate Polymers 84: 33-39.

22. Pawar SN, Edgar KJ (2012) Alginate derivatization: A review of chemistry, properties and applications. Biomaterials 33: 3279-3305.

23. Boontheekul T, Kong H, Mooney DJ (2005) Controlling alginate gels degradation utilizing partial oxidation and bimodal molecular weight distribution. Biomaterials 26: 2455-2465.

24. Kong HJ, Kaigler D, Mooney DJ (2004) Controlling rigidity and degradation of alginate hydrogels via molecular weight distribution. Biomacromolecules 5: 1720-1727.

25. Gomez CG, Rinaudo M, Villar MA (2007) Oxidation of sodium alginate and characterization of the oxidized derivatives. Carbohydrate Polymers 67: 296-304.

26. Qin Y, Chen J (2011) Absorption and release of zinc ions by alginate fibers. Journal of Textile Research 32: 16-19.

27. Li L, Jiang X, Guan H, Wang P (2011) Preparation, purification and characterization of alginate oligosaccharides degraded by alginate lyase from Pseudomonas sp.HZJ216. Carbohydrate Research 346: 794-800.

28. Luan LQ, Nagasawa N, Ha VTT, Hien NQ, Nakanishi TM (2009) Enhancement of plant growth stimulation activity of irradiated alginate by fractionation. Radiation Physics and Chemistry 78: 796-799.

29. Yan GL，Guo YM，Yuan JM，Liu D, Zhang BK (2011) Sodium alginate oligosaccharides from brown algae inhibit Salmonella Enteritidis colonization in broiler chickens. Poultry Science 90:1441-1448.

30. Zhang Q, Jiang X, Guang H (2003) Bioactivities of oligosaccharides and the potential application of marine oligosaccharides. Chinese Journal of Marine Drugs 3: 51-55.

31. Zhang Y, Luo F, Yao Z (2014) Research progress about biological activity of sodium alginate oligosaccharides. China Brewing 33: 5-8.

32. Steiner AB (1947) Manufacture of glycol alginates. US Patent 2,426,215.

33. Steiner AB, McNeely WH (1950) High-stability glycol alginates and their manufacture. US Patent 2,494,911.

34. Anderson DM, Brydon WG，Eastwood MA, Sedgwick DM (1991) Dietary effects of propylene glycol alginate in humans. Food Additives & Contaminants 8: 225-236.

35. Liu H, Pang J, Wang X (2017) Effect of propylene glycol alginate on rheological and baking properties of dough. Science and Technology of Cereals, Oils and Foods 25: 1-4.

36. Liu R, Fan S, Wang X (2018) Study on the bread quality improvement by different viscosity propylene glycol alginate (PGA). China Food Additives 6: 137-140.

37. Liu R, Jiang J, Yang Y (2016) Effect of low-esterification PGA with different concentrations on the quality of noodles. China Food Additives 8: 148-152.

Henry Publishing Groups, Glanmire, Cork, Republic of Ireland, T45 KD66
Tel: +353 98010312; E-mail: contact@henrypublishinggroups.org
https://www.henrypublishinggroups.com/