

FOOD HYDROCOLLOIDS

**Structures, Properties,
and Functions**

**Edited by
Katsuyoshi Nishinari and
Etsushiro Doi**

Food Hydrocolloids

Structures, Properties, and Functions

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Food Hydrocolloids

Structures, Properties, and Functions

PREFACE

It is now well recognised that the texture of foods is an important factor when consumers select particular foods. Food hydrocolloids have been widely used for controlling in various food products their viscoelasticity, emulsification, gelation, dispersion, thickening and many other functions. An international journal, FOOD HYDROCOLLOIDS, launched in 1986 has published a number of stimulating papers, and established an active forum for promoting the interaction between academics and industrialists and for combining basic scientific research with industrial development.

Although there have been various research groups in many food processing areas in Japan, such as fish paste (kamaboko, surimi), soybean curd (tofu), agar jelly dessert, kuzu starch jelly, kimizu (Japanese style mayonnaise), their activities have been conducted in isolation of one another. The interaction between the various research groups operating in the various sectors has been weak. Symposia on food hydrocolloids have been organised on several occasions in Japan since 1985. Professor Glyn O. Phillips, the Chief Executive Editor of FOOD HYDROCOLLOIDS, suggested to us that we should organise an international conference on food hydrocolloids. We discussed it on many occasions, and eventually decided to organise such a meeting, and extended the scope to include recent development in proteinaceous hydrocolloids, and their nutritional aspects, in addition to polysaccharides and emulsions.

The international conference in Tsukuba was organised by the Japanese Society of Food Hydrocolloids under the auspices of many relevant societies and organisations. It was an epoch-making-event for Japanese researchers as well as overseas participants working in the field of food hydrocolloids. Many of the participants who know each other through their publications, could benefit from face-to-face discussions during tea time, lunch time, poster sessions and

industrial exhibitions. The social and scientific exchange was so fruitful that all the participants felt very pleased to be there. We are particularly grateful for the overwhelming response to the success of the meeting. As a result, it has been decided to organise the 2nd International Conference on Food Hydrocolloids at Ohio State University in USA during the first week of September 1994.

This book we trust will convey the essence and enthusiasm of the conference. Papers included in this book are classified into the following six groups:

- * *Polysaccharides*
- * *Functional Properties*
- * *Proteins*
- * *Emulsions*
- * *Interactions*
- * *Nutrition and Physiology*

The information collected in this book supplies valuable scientific information and provides suggestions for further developments which will further assist our understanding and utilisation of food hydrocolloids.

Katsuyoshi Nishinari
Etsushiro Doi

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STRUCTURAL ASPECTS OF SOME FUNCTIONAL POLYSACCHARIDES

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INTRODUCTION

Carbohydrate polymers are widespread in nature, and play important roles in all life-stages of the organisms. Biological, physiological and other functions of natural polysaccharides are summarized in Table 1. Although in a nutritional point of view, the most important function of carbohydrate must provide biological fuel, which is reserved in the form of starch or glycogen, some undigestible polysaccharides, either plant hemicelluloses or microbial polysaccharides, have recently attracted attention because of the physiological effect as dietary fibers. In the field of food science and technology, pectic substances in plant cell wall matrix, and a variety of gum exudates, have long been used as emulsion stabilizers, water absorption agents, gelling and thickening agents. In addition, some microbial polysaccharides having unique properties, elaborated extracellularly in abundant amounts, have recently been utilized as a gel-forming agent or a food-packing film. In Table 2 natural polysaccharides as food hydrocolloids are classified according to their biological sources. Although functionality of individual polysaccharides are closely related to their own molecular shapes, we must first look into the primary structure of the building units, *i.e.* the carbohydrate components, mode of linkages and their sequential arrangements. In this symposium structural correlations with functionality of some plant and microbial polysaccharides, important food hydrocolloids, are discussed.

Table 1. Functionality and utilization of polysaccharides.

Biological functions

- a) Cell wall architecture (plants and microorganisms)
- b) Hydration or gelation of intracellular fluids
- c) Cell-cell recognition (cell surface)
- d) Stimulation of host defense

Physiological functionality

- a) Nutrition (biological fuel)
- b) Dietary fiber
- c) Source of functional oligosaccharides

Functionality as food hydrocolloid

- a) Stabilizer
 - b) Thickener
 - c) Gelling agent
 - d) Water-holding agent
-

GENERAL MOLECULAR STRUCTURE OF NATURAL POLYSACCHARIDES AND METHODS FOR STRUCTURAL ANALYSIS

The rheological characteristics of natural polysaccharides are principally related to their molecular conformations, which may be regulated by the sequences of carbohydrate chains. Therefore, it must be necessitated to know their chemical structure, especially, the mode of glycosidic linkages in the building units. Even in homoglycans, there are wide varieties in modes of glycosidic linkages, arrangements of glycosyl residues, and molecular shape, either a linear or branched molecule. For example, there are a variety of glucose polymers occurring in nature as classified:

	Glucosidic linkage	Name	Occurrence
α-D-GLUCANS;	(1→4) linear	amylose	plant
	(1→4) 1,6 branch.	amylopectin	plant
	(1→4) 1,6 branch.	glycogen	mammal
	(1→4) ₃ (1→3)	elsinan	<i>Elsinoe</i> sp.
	(1→6) 1,3 branch.	dextran	<i>L. mesenteroides</i>
	(1→3) 1,6 branch.	(mutan)	<i>Str. mutans</i>
	(1→3)G(1→4)	nigeran	<i>Asp. niger</i>
β-D-GLUCANS;	(1→4) linear	cellulose	plant cell wall
	(1→4) _n G(1→3)	cereal gum	endosperm
	(1→4) ₂ G(1→3)	lichenan	lichen
	(1→3) linear, DP 30	laminaran	seaweed
	(1→3) linear	curdlan	<i>Alc. faecalis</i>
	(1→3) less branch.		yeast cell wall
	(1→3) 1,6 branch.		fungi, mushroom
	(1→2) cyclic		<i>Arg. tumefaciens</i>

These plant and microbial glucans of either α - or β -configuration, with different linkages, exhibit their specific properties and functionality. For instance, amylose and cellulose, both linear molecules build up with (1→4)-linked D-glucose residues, but with different anomeric linkages (α -, or β -), giving different physical properties and enzymic

Table 2. Polysaccharides as food hydrocolloid.

PLANT POLYSACCHARIDES

Starch and its modified products

Seed gums

Cereal gums (1,3/1,4- β -Glucan)

Galactomannans (Guaran, Locust bean, Tara bean etc.)

Xyloglucan (Tamarind)

Tuber gums

Glucomannan (Konjac), Inulin

Cell wall constituents

Cellulose (chemical modified)

Fucoxylglucan

Arabinoxylan (monocot), Arabinogalactan (dicot)

Pectinic substances (Rhamnogalacturonan, Galacturonan etc.)

Exudate mucilages

Gum arabic, Gum tragacanth, Karaya gum and others

SEAWEED EXTRACTS

Agar (Gal., 3,6-AnhydroGal)

Carrageenan (sulfated Gal), Fucoidan

Alginic acid (Guluro-mannuronide)

Laminaran

MICROBIAL POLYSACCHARIDES

Neutral polymers

Dextran (α -1,6 glucan)

Pullulan (α -1,6/1,4); low viscosity, film sheet

Elsinan (α -1,3/1,4); high viscosity, film sheet

Curdlan (β -1,3); heat-gelation

Scleroglucan (6-*O*-branched β -1,3)

Levan (2,6-fructan)

Acidic polymers

Xanthan (G1A, Pyruvate, Man, 4Glc β -); synergistic gelation effect

Gellan (\rightarrow 3Glc β \rightarrow , \rightarrow 4G1A β \rightarrow , \rightarrow 4Rha α \rightarrow , \rightarrow 4Glc β \rightarrow); gel forming

Others having potential utilization

Welan gum (Kelco)

Rhamsan gum (Kelco)

B. polymyxa acidic Ps

PS 1004 from methnol (Ga, Man, Al, G1A)

T. fuciformis acidic PS (G1A, \rightarrow 3Man α \rightarrow)

Acetobacter sp. acidic PS (G1A, Gal, \rightarrow 4Glc β \rightarrow)

susceptibilities. In a similar way, (1 \rightarrow 3)-linked α - and β -D-glucans possess significantly different conformations from each other, shown in Fig. 1. For instance, curdlan, a gel-forming bacterial glucan¹, and the backbone moiety of many antitumor, branched β -D-glucans, e. g., scleroglucan, lentinan, schizophyllan and other fungal glucans, consist of β -(1 \rightarrow 3) glucosyl chains. They are mostly present as a triple helical strands, which are most likely responsible for their host-mediated antitumor activity². In contrast, the (1 \rightarrow 3)- β -D-glucosyl chain, which forms a backbone of the dental cariogenic α -glucan ("mutan"), elaborated by *Strept. mutans* may have a ribbon-like single-

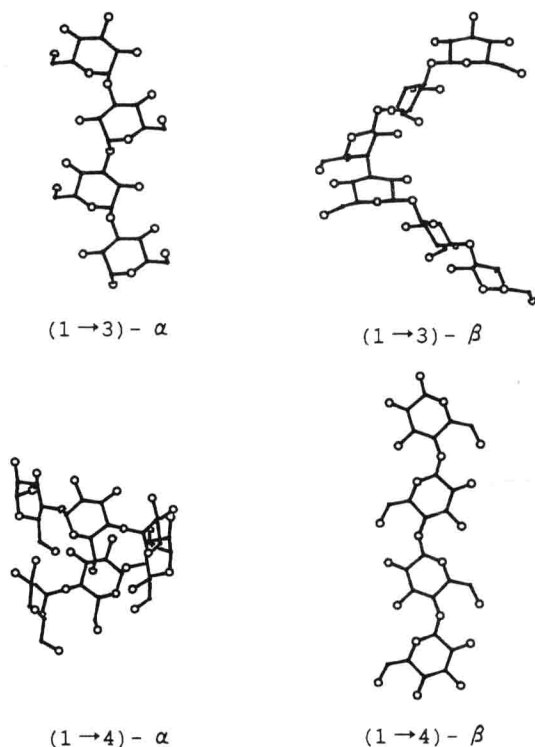


Fig.1 Crystalline conformation of α - and β -D-glucans.
(Courtesy of Dr. K. Ogawa, RIAT, University of Osaka Prefecture)

chain conformation, which may give an insolubility characteristic; the adhesive characteristic may be exhibited by α -(1→6)-linked D-glucosyl side chains.

Many of natural polysaccharides, currently used as potent food hydrocolloids, such as, emulsion stabilizer, water-holding, thickening or gelling agents, are obtained from various tissues of plants, *i. e.* seeds, tubers, and exuded mucilages, and also from seaweed extracts (see, Table 2). Dextran was introduced into pharmaceutical industry as a blood plasma substitute after the second world war. Then, xanthan and pullulan, and recently gellan gum have also been put on commercial market, and some other microbial polymers have attracted attention because of their potential utilizations, as will be discussed later.

Most of these polysaccharides are heteropolysaccharides comprising different carbohydrate components. Some contain charged groups, *e. g.*, carboxyl, sulfonyl, or amino groups. Their unique rheological characteristics are basically attributable to the molecular shapes as well as localization of the charged groups. Fig.2 shows viscosities of aqueous solutions of typical natural gums. For instance, galactomannans, *e. g.*, guar and locust bean gum, give high viscosity, most probably due to the characteristic features as the linear chain of the β -(1→4)-linked mannan and solubility property may be attributed to the presence of regularly arranged α -galactosyl branches. On the other hand, gum Arabic, a multiply branched acidic heteropolysaccharide, shows extremely