Physical properties of the mixed gels of κ-carrageenan with locust bean gum and gels prepared from commercially available gelling agents

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Introduction

As the aging of society progresses, the number of cases of eating disorders caused by tooth-loss and the reduced function of swallowing has increased. Therefore, the needs for appropriate food preparation, responding to the increased number of such cases, have become apparent. Teas and juices have a viscosity suitable for those who have difficulty in swallowing. Some alterations have been made to the textures of puddings and jellies using gelling agents to make consumption easier[1], because these agents are highly viscoelastic and easily change their shapes while passing through the throat.

Starches and polysaccharide thickeners (galactomannan) are used as thickening agents; however, sufficient details about these products are not available. In any case, they have advantages such as liquids can be thickened by a simple mixing process; they are easy to dissolve and effective in small amounts; and they do not alter taste. Polysaccharide thickeners[2] are used as gelling agents to make jellies by mixing carrageenan, obtained from marine algae, and locust bean gum.

Jellies, due to their fresh and cool texture, have long been the most popular dessert in summer time. Recently, demand for jellies has become high throughout the year. Not only the taste, but also the attractive appearance of jellies has added to their popularity. However, because these jelly products are prepared by using the characteristics of gelling agents, which are solidified with a large volume of water, the quality of the jelly depends on the gelling agent itself. Among gelling agents, mixed gels of carrageenan and locust bean gum are widely used because of their convenience in production and distribution compared to conventional agar-agar or gelatin. Companies produce their own gelling agents with different mixing ratios. By changing the mixing ratio, the texture of the jelly can be adjusted and a delicate flavor can be imparted. Not so much for general dessert jellies, but for food taken by the elderly requiring care, in particular, it is important to fully understand the characteristics of each gelling agent and to choose suitable one.

The different gelling agents with different mixing ratios of carrageenan to locust bean gum were tested and the product quality and taste were examined. Also, a study on commercially available gelling agents was conducted to identify their nature.

Materials and Methods

Samples

1. Mixed gels

Carrageenan: Carrageenan is a natural polysaccharide obtained from red seaweed in the same way as agar-agar. Major seaweed materials include Eucheuma, Iridaea, and Gigartina species, and they are used of the industrial level.[3] Even though the raw materials used are different, carrageenan can be divided into three fractions from the constituent sugars; namely κ, ι, and λ. Kappa, ι, and λ-carrageenans and their sugar structures are shown in Table 1. Kappa-carrageenan CS-47 of San'ei Chemical Co., Ltd. was used in this experiment.

Kappa and ι-carrageenan solutions form gels when they are cooled. The melting temperature

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Table 1. Composition raito of κ, ι and λ-carrageenan (%)

	kappa	iota	ramda
galactose group	29	20	45
sulphate group	26	31	35
3,6-anhydro group	23-28	20-30	0-2

of carrageenan is about 70℃, and their gelling temperatures are 40-45℃, and 60-65℃, respectively, and the lowest concentration for gelling is about 0.7%. The gelling mechanism[4] is shown in Fig. 1; while κ-carrageenan forms a solid gel with a double helix structure, an ι-carrageenan gel becomes elastic and soft because 2-sulfate groups in 3,6-anhydrogalactose prevents coagulation. Ramda-carrageenan does not gelatinize and its solution has high viscosity. Kappa-carrageenan increases its strength with the co-existence of cations such as K. Iota-carrageenan forms a highly viscoelastic gel due especially to the existence of Ca.

Locust bean gum: Locust bean gum is extracted by grinding the seeds (kernels) of the carob tree, which grows in the Mediterranean region. It is a non-ionic, neutral polysaccharide. It is a galactomannan consisting of galactose and mannose, and the structural ratio of these is one to four, respectively. Locust beean gum of Mero-Rousselot-Satia Co. Ltd. was used in this experiment. It disperses in cold and hot water, and is soluble when heated at 80℃ for about 15 minutes. It is not affected by pH. It cannot gelatinize by itself.

2. Commercially available gelling agents

Eight kinds of commercially available gelling agents were used: namely, Parl-agar (P), Ina-agar L (I), Soagina M702 (S-1), Soagina M708 (S-2), Uni-agar C-1 (U-1), Uni-agar J-9 (U-2), Uni-agar J-28 (U-3), and Uni-agar J-50 (U-4). All of them are made from a combination of κ- carrageenan and locust been gum, and are in popular use. They were bought at the food counter of a department store in Tokyo.

Preparation of Samples

1. Mixed gels:

Mixed gels were prepared by the usual method to obtain a concentration of 1.0%[5]. The mixture ratios of κ-carrageenan and locust beean gum were set for making gel, namely ; 10:0, 9:1, 8:2, 7:3, 6:4, 5:5, and 4:6. Sucrose was added to each sample for a final concentration of 10 percent. To measure the texture properties, each solution was poured into a jelly glass of 50mm in diameter and 18mm in height. To measure the rupture properties, each solution was poured into a cylindrical glass cell of 20mm in diameter and 18mm in height. All of them were cooled for twenty-four hours to obtain sample gels.

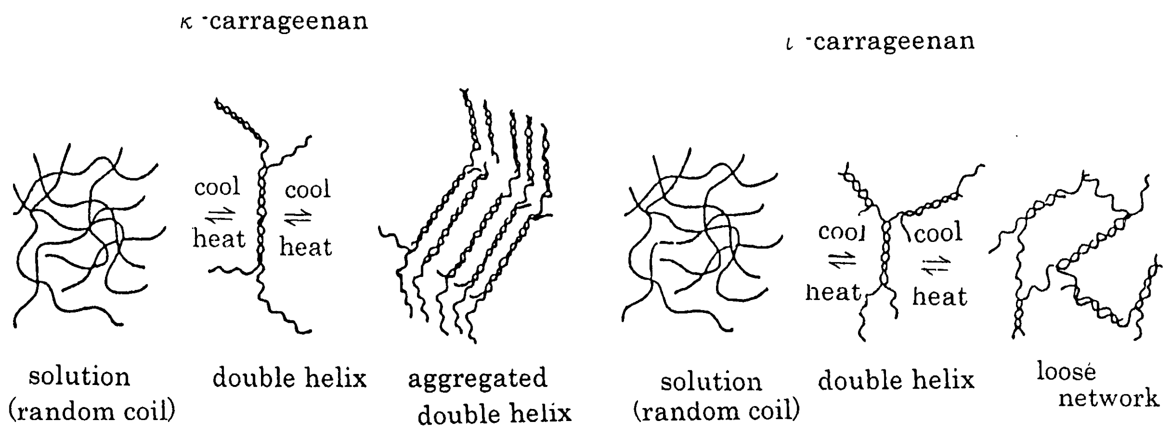

Fig.1 Gelling mechanism of κ and ι-carrageenan

2. Gels using commercially available gelling agents:

The concentrations of commercially available gelling agents are within the range of 1 % to 4%, depending upon their use. The difference in concentration comes from the fact that each manufacturer has tried to improve its product in various ways. Some add glucose to facilitate dispersion, because carrageenan and locust bean gum do not disperse well in cold water. Some add potassium chloride, which works selectively on κ-carrageenan, to improve handling and texture. This changes the mixture ratio in each gelling agent. The addition of sucrose and the preparation of gels for the experiments were conducted in the same manner as mixed gels.

Measuring methods of gels

Texture properties: The texture properties were measured by compressing the sample twice in a rheometer (Yamaden K.K.), using a plunger of 12mm diameter, a clearance of 65mm and a compression rate of 5mm/s.

Rupture properties: The rupture properties were measured by using the above-mentioned rheometer using a 12mm diameter plunger to compress each sample to 80 % of its original height at a compression rate of 50 mm/s.

Sensory evaluation: The sensory evaluation was performed by the semantic differential (SD) method. The evaluation panel was composed of 20 laboratory assistants and college students. Each panelist had previously been trained. Sensory profiles based on those of Yoshida[6] and Yoshikawa[7] were developed, each attribute being evaluated on a rating scale of 5 (-2 to +2) from a median zero value for the characteristics listed in Table 2. Based on the average values thus obtained, radar charts were constructed.

All sample gels were covered with parafilm to prevent drying during storage and stored and tested at 25℃.

Table 2. Sensory characteristics evaluated by Semantic Differential

		very -2	slightly -1	0	slightly +1	very +2	
1 Hardness	soft						hard
2 Smoothness	rough						smooth
3 Elasticity	plastic						elastic
4 Brittleness	brittle						ductile
5 Overall acceptability	unpalatable						palatable

Results and Discussion

1. Characteristics of mixed gels

1) Texture and Rupture properties

Texture properties: 1%-gels with different mixing ratios of κ-carrageenan with locust bean gum were tested for hardness and cohesiveness. The results are shown in Table 3. Hardness reached maximum at a mixture ratio of 7:3 and subsequently gradually decreased, but cohesiveness increased, as the content of locust bean gum increased. However, the difference between the gels was small.

Rupture properties: Stress-strain curve (Fig.2) and Table 4 show rupture stress, rupture strain, and rupture energy. Rupture stress and rupture energy reached maximums at a mixture ratio of 7:3, but rupture strain progressively increased as the content of locust bean gum increased. The rate of rise decreased after reaching a maximum at the mixture ratio of 7:3, causing the softening of the gels.

Fig.2 Stress-strain curves of mixed gels

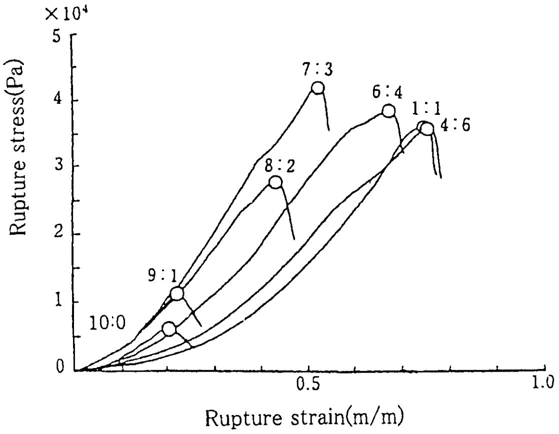

Table 3. Texture Properties of mixed gels

mixture ratio C−L	hardness $\times 10^4$(Pa)	cohesiveness $\times 10^{-1}$
10 : 0	0.95	5.39
9 : 1	1.47	4.95
8 : 2	2.71	4.91
7 : 3	3.98	5.05
6 : 4	2.65	6.05
5 : 5	2.05	6.34
4 : 6	1.05	6.27

C: κ-carrageenan L: locust bean gnm

Table 4. Rupture properties of mixed gels

mixture ratio C−L	rupture stress $\times 10^4$(Pa)	rupture strain $\times 10^{-1}$ (m/m)	rupture energy $\times 10^3$ (J/m^3)
10 : 0	0.60	2.20	0.50
7 : 3	4.30	5.30	9.80
1 : 1	3.20	6.60	7.50

C: κ-carrageenan L: locust bean gnm

2) Sensory evaluation

The results of a sensory evaluation of the mixed gels are shown in the radar chart (Fig.3), which shows three distinct results: results, namely that of 1% κ-carrageenan (A), 7:3 mixed gel (B), and 1:1 mixed gel (C). As the content of locust bean gum increased, the gel became harder with more elasticity and strength; as a result, the gel was unfavorable in terms of taste. Sample (B) was most preferred in the overall acceptability. It can be said that it is preferable to limit the addition of locust bean gum to a small amount.

Locust bean gum consists of mannose as its main chain and galactose as its side chain (Fig.4). The ratio of mannose and galactose is 4 (3.7 for this sample) : 1. The smooth zone of the main chain of mannose without the side chain of galactose of locust bean gum is connected to the double helix of κ-carrageenan. This increases the strength of the network structure and gives the specific elasticity. It is believed that κ-carrageenan shows a synergism of elasticity and hardness when used together with locust bean gum.

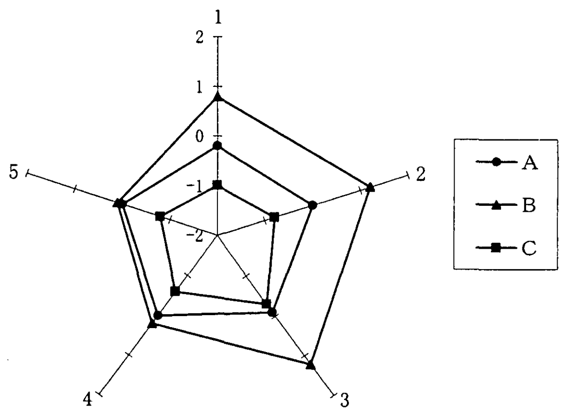

Fig.3 Rader chart of texture profiles for mix gels Nos.1-5 are the characteristics defined in Table 2.

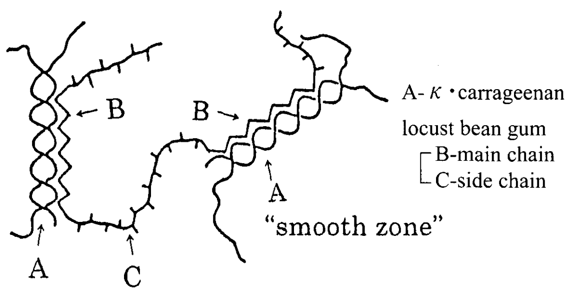

Fig.4 Synergism of κ-carrageenan and locust bean gum

2. Characteristics of gels prepared from commercially available gelling agents

1) Texture and Rupture Properties

Texture Properties: Fig.5 shows hardness and cohesiveness. Hardness is notably small for S-1 and large for I, and there is a 4.6-fold difference between the minimal hardness and the maximal hardness, showing a great difference among gelling agents; however there is no remarkable difference in cohesiveness.

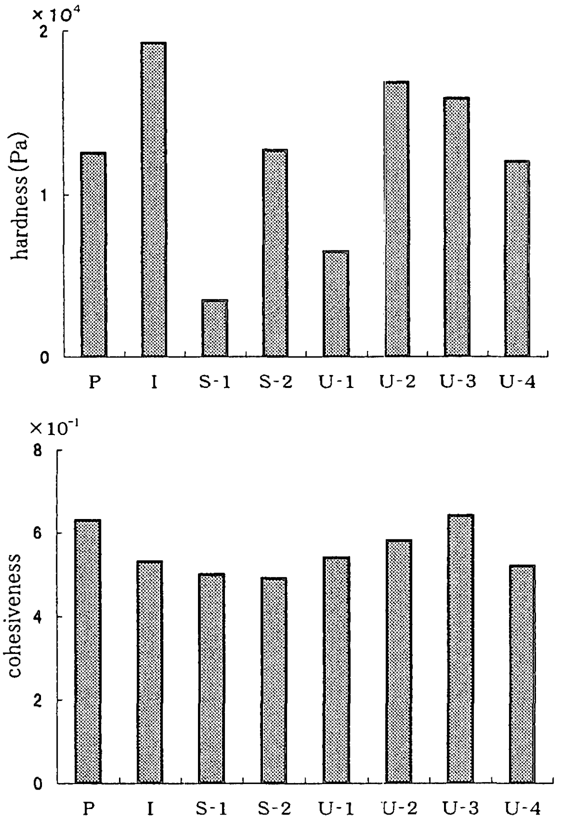

Fig.5 Texture properties of gels prepared from commercially available gelling agents

Rupture Properties: Fig.6 shows stress-strain curves of 8 different gelling agents. Rupture stress, rupture strain, and rupture energy are shown in Table 5. P, U-2, U-3, U-4, and I showing similar patterns of stress-strain curves. These patterns are approximately consistent with those for different mixing ratios of κ-carrageenan and locust bean gum of 7:3 and 6:4. S-1, S-2, and U-1 show different stress-strain curves. The degree of rise of U-1 was minimum, and there was no considerable difference in other gels. The degree orf rise is associated with the elasticity of gels, and a gel with a small degree of rise seems to be soft and ductile. As shown in Table 5, the rupture energies of P, U-4, and U-3 show nearly the same values, and these 3 products have similar characteristics in rupture properties. S-1 shows the lowest rating for both attributes, with substantially different rupture properties from other gels.

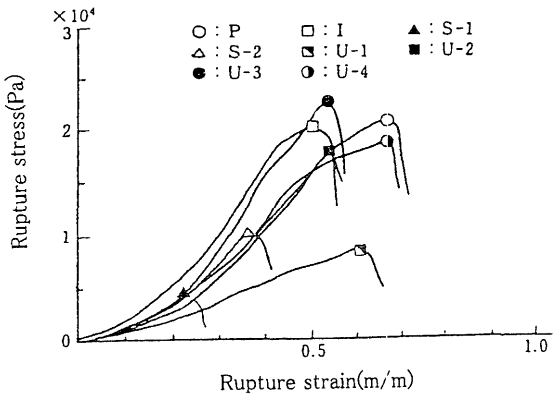

Fig.6 Stress-strain curves of gels prepared from commercially available gelling agents

Table 5. Rupture properties of gels prepared from commercially available gelling agents

Sample	rupture stress $\times 10^4$ (Pa)	rupture strain $\times 10^{-1}$ (m/m)	rupture energy $\times 10^3$ (J/m^3)
P	2.00	6.67	5.52
I	2.05	5.23	4.51
S-1	0.38	2.18	0.35
S-2	1.01	3.60	1.27
U-1	0.87	6.04	2.46
U-2	1.79	5.55	3.57
U-3	2.40	6.08	5.15
U-4	1.89	6.84	5.64

2) Sensory evaluation

The radar chart in Fig. 7 shows the results of a sensory evaluation. S-1 shows a remarkable difference in patterns. Characteristics can be roughly classified as follows: U-3, U-4, and I are elastic, hard, and strong. U-1 is easily breakable. S-2 is palatable. P is elastic and strong. These characteristics of gels show a correlation to the

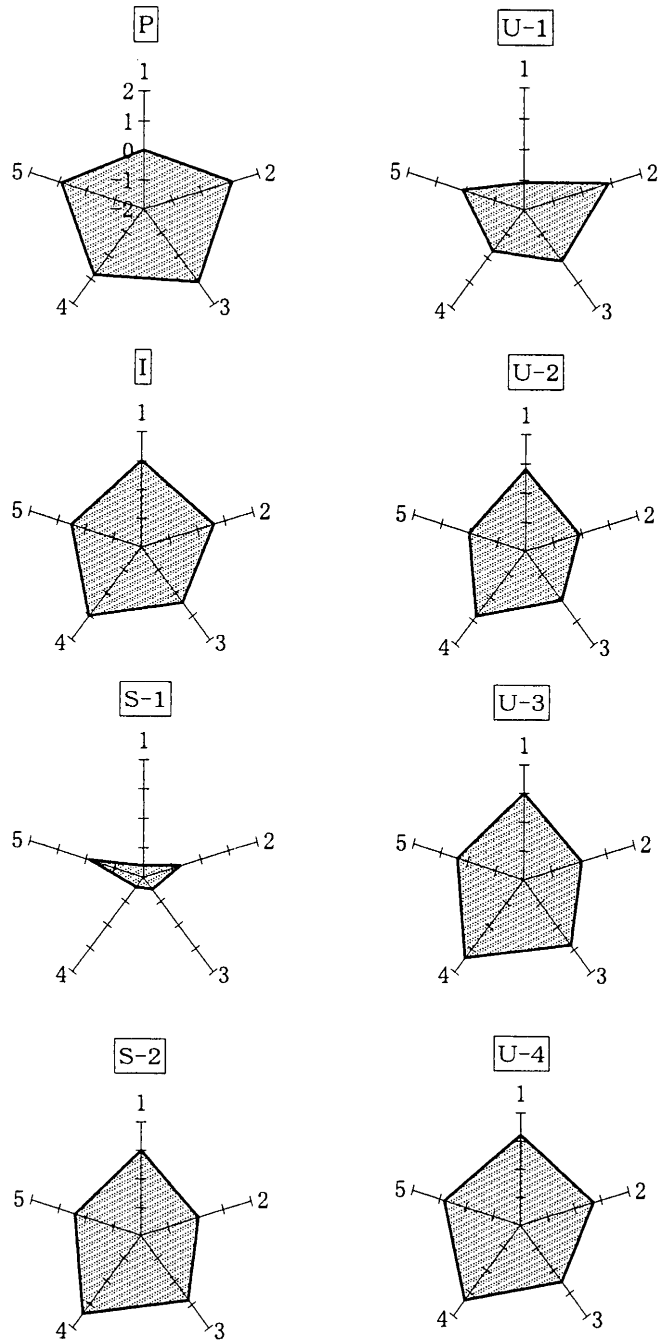

Fig.7 Rader chart of texture profiles for gels prepared from commercially available gelling agents
Nos.1-5 are the characteristics defined in Table 2.

results of a study of their physical properties. From the above results, it is considered that U-3, the hardest gel with extremely high rupture stress and rupture strain, can be transformed into one similar to U-2 by reducing consistency by 0.1%. S-1 is characteristic of a fragile carrageenan gel, U-1 has a smooth texture similar to a gelatin with high elasticity and suppleness, and U-3 and I form a gel with high elasticity and strength. All of these features point out the large differences in gelling agents in the sensory evaluation.

Appropriate selection of gelling agents makes it easier to obtain a gel with a favorable texture that is suitable for its application and desired taste. The main component of these gelling agents is a polysaccharide, which is a material used in non-caloric food as a source of dietary fiber. Gelation occurs at normal room temperature the same as agar-agar; therefore, unlike gelatin, which requires cooling for coagulation, temperature control is easy. Mixed gels of κ-carrageenan and locust bean gum have a high water retention capacity. All of these are advantageous in gelling agents. They have the potential for a wide range of applications such as gelling agents of dessert jellies for household and for mass production, and as a substitute for gelatin in food for the elderly requiring care. The demand for them is increasing.

Summary

1. Gels with different mixing ratios of κ-carrageenan and locust bean gum were prepared and comparative studies were conducted on the texture and rupture properties, as well as a sensory evaluation. Hardness, rupture stress, and rupture energy reached maximum at a mixture ratio of 7:3, and cohesiveness and rupture strain increased as the content of locust bean gum increased. In the sensory evaluation, as the content of locust bean gum increased, the gels became harder and stronger, giving undesirable results. The more favorable result was obtained at a mixture ratio of 7:3.

2. Eight gelling agents, which are available on the general market, were tested with the same physical property measurements and a sensory evaluation, as mixed gels. Although hardness varied among gelling agents, the difference in cohesiveness was minute. Rupture properties show a remarkable 16-fold difference between the lowest and the highest. Results of the sensory evaluation indicated a correlation between sensory perception and physical properties of these gels. Since there are large differences among gelling agents, it is important to choose an appropriate gelling agent based on knowledge of the characteristics of each gelling agent.

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