Curdlan Properties for Application in Fat Mimetics for Meat Products

TAKAHIRO FUNAMI, HIDEO YADA, and YUKIHIRO NAKAO

ABSTRACT

Gelling characteristics and viscoelastic properties of aqueous suspensions of curdlan were investigated by dynamic viscoelasticity measurements. The mechanical spectrum of the suspension was similar to that of weak gels, suggesting the suspension has a well-regulated particle-alignment with yield stress. Curdlan reached the highest moisture absorption rate within the temperature range in which the most significant moisture loss of meat occurs. These results suggest that curdlan could be an effective main ingredient in fat mimetics for meat products. Nonfat sausages using the curdlan-based fat mimetics were prepared and evaluated by a creep test and indicated curdlan was effective as a fat replacer in such systems.

Key Words: curdlan, gel, dynamic viscoelasticity, meat products, fat mimetics

INTRODUCTION

CURDLAN IS A POLYSACCHARIDE PRODUCED BY A MICROORGANISM, *Alcaligenes faecalis* var. *myxogenes* (Harada et al, 1966). Curdlan is a linear homopolymer of D-glucose with β-1,3-glucosidic linkages, and its aqueous suspension is capable of forming a gel only by heating. Curdlan forms two types of gels depending on its heating temperature. One is obtained when the aqueous suspension is heated to 55–60°C and then cooled to below 40°C and termed low-set gel. The other requires its aqueous suspension to be heated above 80°C and is termed high-set gel (Harada et al., 1987). The texture and functional properties of the two types of gels have been demonstrated to be quite different as the high-set gel has a more firm and resilient texture (Miwa et al., 1994). The low-set gel is thermo-reversible similar to agar-agar and gelatin, whereas the high-set gel is thermo-irreversible and very stable at low temperatures such as freezing and also at high temperatures as in retorting. Moreover, since the high-set gel remains tasteless, odorless, and colorless even after severe temperature conditions, curdlan is used in frozen and retorted foods (Nakao et al., 1991). Curdlan has been introduced to the Japanese market to improve texture and water-holding capacity of processed foods or to create new types of foods based on its gelling properties (Harada et al., 1993; Miwa et al., 1994). Curdlan has been approved as a food additive in the U.S. (Anonymous, 1996; Post, 1997).

In the U.S., sales volumes for almost every category of low-fat food products are increasing and emphasis on the health claim for low-fat foods is expected to continue (Russo, 1993). Low-fat meat and poultry products are predicted to show average sales increases of 25.5% and 22.5% per year, respectively.

There are many fat mimetic systems available in the food industry. Such systems are within three general categories: protein-based, carbohydrate-based, and fat-based. Each of them exhibits different functional properties that provide advantages, as well as limitations, in applicable food ranges or replacement levels of fat (El-Magoli et al., 1995). The ultimate goal for a fat mimetic system is to achieve the complete texture and flavor profiles of the fat itself. This has not been accomplished with any single ingredient except for synthetic fat. The most practical way to mimic fat is widely proposed to be by using a combination of materials, with food hydrocolloids as the main ingredient (Glicksman, 1991). Curdlan can be considered to have notable potential as a fat mimetic system by itself or in conjunction with other hydrocolloids.

Our objective was to study the rheological characteristics of curdlan, especially the gelling characteristics and viscoelastic properties of aqueous suspensions. In addition, nonfat sausages using a curdlan-based system were prepared and evaluated to determine the effects of curdlan as a fat replacer in meat products.

The authors are affiliated with the Vitamin & Food research & Development Dept., Vitamin & Food Division, Takeda Chemical Inc., Ltd., 17-85, 2 Chome, Juso-Honmachi, Yodogawa-ku, Osaka 532, Japan.

MATERIALS & METHODS

Materials

Curdlan and microcrystalline cellulose (average particle size 50 μm) were provided by Takeda Chemical Industries, Ltd. Modified tapioca starch was provided by Japan NSC Ltd. (Tokyo, Japan). Curing agent (a mixture of 55% sodium pyrophosphate anhydride, 25% sodium metaphosphate, 11% L-sodium ascorbate, 7% corn syrup solids, and 2% sodium nitrite) and corn syrup solids (DE 25) were purchased from Takeda Chemical Industries, Ltd. Frozen boneless pork was obtained from a local wholesaler. The pork was thawed in a refrigerator overnight, all mechanically trimmable visible fat and connective tissue were removed and cut into 25-mm cubes. The pork cubes were ground through a 3-mm grinder plate. The moisture of the minced pork was calculated by measuring the weight loss after heating at 105°C for 7h, and the pH was determined using an F-14 pH meter (Horiba, Kyoto, Japan) by measuring a 10-fold water dispersion of the particles.

Preparation of curdlan aqueous suspensions

All curdlan suspensions were prepared on a percent w/w basis. Curdlan aqueous suspensions were prepared by two methods: by dispersing curdlan in cold water or in warm water. For the cold water dispersion, curdlan powder was dispersed in water at 25°C with an AM-8 homogenizer (Nihon Seiki Co., Ltd., Tokyo, Japan) and deaerated under vacuum. The dispersing rate was fixed at 13,000 rpm and agitation time was varied from 5 to 15 min depending on concentration. Aqueous suspensions obtained by this method were used for dynamic viscoelasticity (strain sweep, frequency sweep, and temperature ramp), viscosity and steady flow measurements, and differential scanning calorimetry (DSC) analysis. The pH of suspension for DSC analysis was adjusted by hydrochloric acid because curdlan suspension had a buffering effect. For warm water dispersion, curdlan was first dispersed in water at 25°C with the same homogenizer before the same volume of hot water at 90°C was added to the 25°C dispersion. This yielded a 55°C suspension of curdlan which allowed the curdlan particles to absorb excess water and swell before forming the final suspension. Then ice was added to the suspension to lower it below 40°C. The suspension was then homogenized with the homogenizer for 5 min and deaerated under vacuum. Dynamic viscoelasticity measurement (temperature ramp) and steady flow measurement (thixotropic hysteresis loop measurement) figures were obtained from these aqueous suspensions.

Dynamic viscoelasticity

Aqueous suspensions of curdlan of various concentrations were placed on the bottom plate of an Ares strain-controlled rheometer (Rheometric Scientific, Piscataway, NJ). Dynamic strain sweep, dynamic frequency sweep, and dynamic temperature ramp measurement were conducted using the rheometer. Dynamic strain sweep measurements from 10^{-1} to 10^2% was performed at 25°C at constant frequency of 6.28 rad/s using parallel plate geometry (gap 1.3 mm, plate dia 50 mm). Dynamic frequency sweep measurement from 10^0 to 10^2 rad/s was performed at various temperatures at constant strain of 1%, which was previously determined by a strain sweep test to fall within the linear viscoelastic region of curdlan aqueous suspension using the same geometry described. Dynamic temperature ramp measurement from 25°C to 90°C at a heating rate of 2°C/min was performed at constant strain of 1% and constant frequency of 6.28 rad/s using the same geometry described. As there were no differences in data from repeated measurements of dynamic viscoelasticity, only one value is reported.

Table 1—Formulation of sausages

Ingredients	Weight (%) Control	Nonfat sausage
Fresh chopped pork (lean)	50	50
Pork fat	20	20
Fat replacer		20
Water	20	
Salt	2.5	2.5
Potato starch	2	2
Sodium caseinate	2	2
Curing agent[a]	0.6	0.6
Smoke flavor	0.5	0.5
Spices	0.4	0.4
Total	100	100

[a]55% sodium pyrophosphate anhydride, 25% sodium metaphosphate, 11% L-sodium ascorbate, 7% corn syrup solids, and 2% sodium nitrite.

Viscosity measurements

Dynamic viscosity measurement from 10^{-1} to 10^2 rad/s was performed at 25°C using a cone and plate (gap 0.05 mm, cone angle 0.04 rad, dia 50 mm). Steady shear viscosity was also measured at 25°C over the range γ = 0.1–100 s^{-1} using the same cone and plate geometry.

Steady flow measurements

Steady flow measurements were performed at 25°C using cone and plate geometry (gap 0.05 mm, cone angle 0.1 rad, dia 25 mm) to obtain flow curves of the curdlan aqueous suspensions. The shear rate was increased from 0 to 800 s^{-1} at 400 s^{-1}/min. From the flow curves, yield stress was calculated by the Casson equation:

$$(\sigma)^{1/2} = (\sigma_0)^{1/2} + \eta_a(\gamma)^{1/2}$$

where σ, σ_0, η_a, and γ each respectively represent shear stress, yield stress, apparent viscosity and shear rate.

Thixotropic characteristics of curdlan suspension were also determined using the same geometry. The shear rate was increased from 0 to 800 s^{-1} at 400 s^{-1}/min, and decreased from 800 to 0 s^{-1} at 400 s^{-1}/min. Again, as there were no differences in the values from repeated measurements, only one value is reported.

Differential scanning calorimetry

Tests were carried out using a Seiko SSC 5200 DSC 120 differential scanning calorimeter (Seiko Instruments Inc., Chiba, Japan). The thermal properties of curdlan aqueous suspensions were analyzed. Samples (50 mg each) were hermetically sealed in 70-μL silver capsules. An equal weight of distilled water was sealed in another capsule as a reference. Then the sample and reference capsules were placed in DSC cells and cooled with ice to 0°C. The capsules were allowed to warm at room temperature to 5°C before the start of the DSC test. The temperature was raised from 5°C to 100°C at a heating rate of 1°C/min or 2°C/min to develop thermal curves. After scanning, the samples were reweighed to verify that no weight loss had occurred. The endothermic incipient temperature T_i and the endothermic peak temperature T_p were calculated from the DSC curves according to the method of Nagano et al. (1992). The endothermic enthalpy change ΔH was also calculated from the DSC curves. The constants used to calculate the parameters were obtained from thermal curves of benzoic acid, diphenyl, or indium. All DSC characteristics were expressed as means of triplicate runs.

Preparation of fat mimetic systems and sausages

For a fat mimetic system, curdlan was first dispersed in water at 25°C using the homogenizer before the same volume of hot water at 90°C was added to the dispersion, which resulted in a 55°C suspension. Ice was then added to bring it to below 40°C. After modified tapioca starch and microcrystalline cellulose were added, the dispersion was homogenized using the homogenizer for 5 min at 13,000 rpm and deaerated under vacuum. The final concentrations of curdlan, modified tapioca starch, and microcrystalline cellulose were 3%, 10%, and 1%, respectively (Table 1). Sausages were formulated using 50% ground lean pork, 20% pork fat, and 20% water as main components. Nonfat sausages were formulated using fat mimetic systems in place of the pork fat. Salt and curing agent were mixed with minced pork using a FC-27D food cutter (Aiho, Aichi, Japan) at 1,700 rpm for 3 min, then other ingredients were mixed for 5 min. The sausage batter was stuffed into a vinylidene chloride tube casing of 30 mm dia (100g per tube), and heated at 75°C for 60 min in a water bath without the smoking process. Lack of the smoking and drying process was the only deviation from a typical commercial pork sausage production. The nonfat sausage using the curdlan-based fat replacer is referred to as "curdlan sausage." Also, "curdlan-blank sausage" represents the nonfat sausage using the fat replacer containing 10% modified starch, 1% microcrystalline cellulose, and 3% corn syrup solids in place of curdlan to adjust solids content of the sausage.

Fat content

Fat was determined after extraction from sausages with a Soxhlet extractor using ethyl ether as a solvent.

Static viscoelasticity

Sample sausages 30 mm dia and 30 mm in height were prepared. Creep measurement was carried out using a Rheoner RE2-33005 (Yamaden Co. Ltd., Tokyo, Japan) with a 20 kgf load cell at 25°C and 70°C. A constant load was applied to the cylindrical sausage using a 40-mm-dia flat plunger for 1 min and then unloaded instantly. The load was applied within 10% to 15% strain, which was in the linear region between stress and strain from preliminary tests. Creep curves (compliance vs time) were analyzed using a 4-element model, consisting of a Maxwell body and a Voigt body connected consecutively to obtain the following parameters; elastic modulus of the Maxwell body (elastic modulus of the Hookean body) E_o), retarding elastic modulus and viscosity of the Voigt body (E_1 and η_1), and viscosity of the Maxwell body (viscosity of the Newtonian body) (η_N). All experimental data were represented as means ± standard deviations for 5 repeated measurements.

RESULTS & DISCUSSION

Dynamic viscoelasticity

Temperature dependence curves were compared (Fig. 1) for dynamic viscoelasticity of 3% curdlan aqueous suspensions. Storage modulus G′ of each suspension started to increase at around 50°C, indicating the swelling of the molecule began at that temperature, though the G' of the suspension prepared by warm water dispersion was larger than that of the suspension prepared by cold water dispersion at below 50°C. This is because curdlan absorbed water in the early stage of the dispersion. Each curve peaked at around 55°C, indicating the maximum water uptake occurred around that temperature. At temperatures above 60°C, the G′ increased with rising temperature, suggesting the formation of the high-set gel, and no significant difference was observed between curves. The frequency dependence patterns of dynamic viscoelasticity were compared (Fig. 2) for 3% curdlan aqueous suspension at various temperatures. Apparent frequency dependence of G′ was observed with increasing temperature between 45°C and 55°C, but at higher temperatures, for example at 75°C, G′ was totally frequency independent. Loss modulus, G″ at 25, 45, and 55°C correlated with the frequency, but G″ at 75°C did not. Mechanical spectra obtained by the frequency sweep measurement are classified into several types, including: dilute polymer solution, concentrated polymer solution, and weak gel (Miyoshi et al., 1994). The mechanical spectrum of the suspension at 45 and 55°C could be classified into a cross between concentrated polymer and weak gel because G′ was larger than G″ throughout the tested frequency range and both G′ and G″ were frequency dependent. This result was directly attributable to the function of curdlan. The mechanical spectrum of the suspension at 75°C, however, could be classified into that of a weak gel or a true gel because G′ was larger than G″ throughout the tested frequency range and both G′ and G″ hardly correlated with the frequency change. This indicates formation of the high-set gel. The frequency dependence of dynamic viscoelasticity of curdlan aqueous suspensions was compared (Fig. 3) at various concentrations. This measurement was performed at 25°C. At each concentration, G′ was continuously larger than G″ throughout the tested frequency range, and G′ was frequency-independent even at low (2 or 3%) concentrations. This suggests that curdlan aqueous suspension had a well-regulated alignment of particles with yield stress. Similar results were also reported in the mixture system of xanthan gum and konjac mannan (Shatwell et al., 1991).

Viscosity measurements

The relationship between dynamic viscosity and steady shear viscosity of 3% aqueous suspension was established (Fig. 4). The viscosity (η) of curdlan suspension under steady shear (large deformation) was apparently lower than dynamic viscosity (η*) (small deformation) under oscillation. This suggests that curdlan suspension behavior was not described by the Cox-Merz rule, and this phenomenon is typical of weak gels (Richardson et al., 1989). That is, "structured" fluids behave differently under small-deformation conditions, where the structure is retained, than under large-deformation conditions, where the structure is destroyed. True solutions, on the other hand, which do not have such structures, yield equivalent results with either small or large deformation forces.

Steady flow measurements

The flow-curves of curdlan aqueous suspensions were compared at various concentrations between 1% and 5% (Fig. 5). Shear-thinning properties were clearly recognizable in each flow curve. Flow curves of the 2 and 3% suspensions were classified into a pseudoplastic with yield stress, whereas flow curve of the 1% suspension was classified into a normal pseudoplastic (Bourne, 1982). Flow curve of the 5% suspension did not follow any of the typical viscous model behavior patterns. The first peak in this curve was related to some kind of shear stress needed to start the sample flow and represents the breakdown of the structure as reported for certain concentrated fluids (Halmos and Tiu, 1981). At high shear rates, however, the flow generally resembled that of a pseudoplastic with yield stress. The yield stress of each suspension calculated by Casson's equation was 0.02 Pa at 1%, 1.6 Pa at 2%, 19.2 Pa at 3%, and 20.2 Pa at 5%. Also in this case, squared coefficient of each regression line determined by Casson's equation ranged between 0.98–1.0. Though some models describe the flow behavior of fluids (e.g., the power law, Bingham, Herschel-Bulkley, and Casson model) (Dervisoglu and Kokini, 1986), we used the Casson model because of the best fit to the flow curves of curdlan aqueous suspensions. The thixotropic hysteresis loop was studied (Fig. 6) for 3% curdlan aqueous suspensions. Dispersing curdlan in warm water increased the thixotropic characteristics significantly compared to cold water dispersion. As

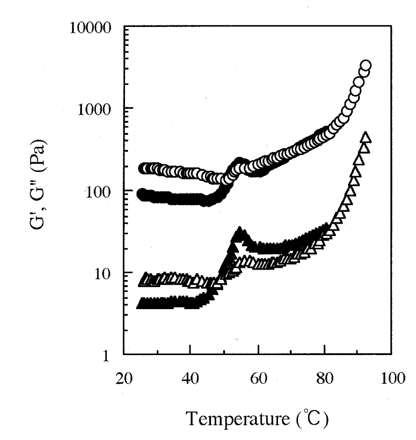

Fig. 1—Temperature dependence curves of dynamic viscoelasticity of 3% curdlan aqueous suspensions. Aqueous suspensions of curdlan prepared by dispersing in cold water or in warm water, then deaerating. The measurement was performed from 25 to 90°C at a heating rate of 2°C/min at constant strain of 1% and at constant frequency of 6.28 rad/s using a parallel plate geometry of 50 mm in diameter. G′, storage modulus; G″, loss modulus. ○ G′, warm water dispersion; ● G′ cold water dispersion; △ G″, warm water dispersion; ▲ G″, cold water dispersion.

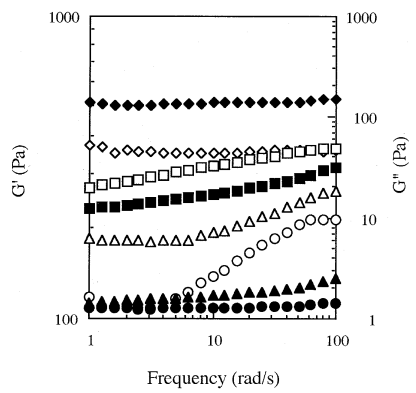

Fig. 2 —Frequency dependence of dynamic viscoelasticity of 3% curdlan aqueous suspensions at various temperatures. Aqueous suspension of curdlan prepared by dispersing in cold water, then deaerating. The measurement was performed from 10^0 to 10^2 rad/s at various temperatures at constant strain of 1% using the same geometry as for Fig. 1. G′, storage modulus; G″, loss modulus. ● G′at 25°C, ▲ at 45°C, ■ at 55°C, and ◆ at 75°C. ○ G″ at 25°C, △ at 45°C, □ at 55°C, and ◇ at 75°C.

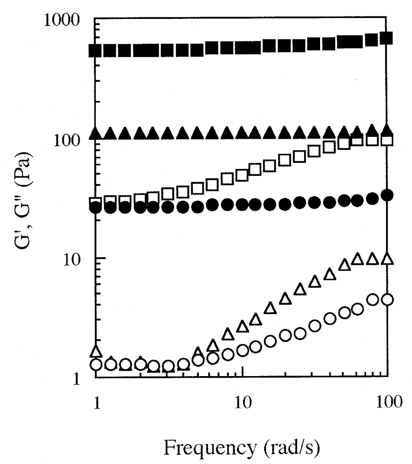

Fig. 3—Frequency dependence of dynamic viscoelasticity of curdlan aqueous suspensions at various concentrations. Aqueous suspension of curdlan prepared by dispersing in cold water, then deaerating. The measurement was performed from 10^0 to 10^2 rad/s at 25°C at constant strain of 1% using the same geometry as for Fig. 1. G′, storage modulus; G″, loss modulus. ● G′ at 2%, ▲ at 3%, ■ at 5%; ○ G″ at 2%, △ at 3%, □ at 5%.

observed in hysteresis loops of cosmetic topical cream (Kawasaki, 1980), the ascending curve showed that the structure of the suspension prepared by warm water dispersion was completely destroyed at shear rates above $500s^{-1}$, although the descending curve gave a smoother line.

Differential scanning calorimetry

The effects of pH were studied (Fig. 7) on DSC characteristics of a 3% curdlan aqueous suspension. Since both T_i and T_p were responsible for the swelling (Konno and Harada, 1991), they were closely related to the dynamic viscoelastic characteristics at each scanning rate. Also, the DSC characteristics including ΔH were not affected by pH.

Functions of ingredients in fat-mimetic systems

These rheological results suggest that curdlan may be an effective ingredient within processed meat products or fat mimetics in certain food systems. The usage and functions of curdlan as a quality improver in such products have been reported (Funami and Nakao, 1996). The function of both curdlan and modified starch in our curdlan-based fat-mimetic system was to provide lubricity, while that of microcrystalline cellulose was to provide a roller effect to smooth out flow properties (Glicksman, 1991). The curdlan suspension, due to its high yield stress and solid-like properties, mainly gave thickening and bodying effects, and the modified starch added creamy slipperiness and adhesiveness. The combined use of curdlan and modified starch functioned as an excellent fat-mimetic system, mimicking the lubricity of fat. Microscopic observation revealed that the average particle size of curdlan in the system was 10-30 µm, so curdlan may also function with a roller action, although the size is relatively larger than those described by Glicksman (1991). The reason the warm water dispersion method was adopted was to increase the viscoelasticity figures, the G' and the thixotropic properties of the system at lower temperatures (Fig. 1, 6). This functions to keep mimic the texture and mouthfeel of fat, including its appearance, especially when it is applied to processed liquid foods such as no- and low-fat dressings, sauces, soups, and spreads.

Table 2—Static viscoelasticity of sausages evaluated by a creep test using a 4-element model[a]

Treatments	Temp °C	E_0[d] 10^5 N/m²	E_1[d] 10^5 N/m²	η_1[d] 10^6 Pa·s	η_N[d] 10^7 Pa·s
Control (20% fat)	25	3.03±0.10	7.68±0.08	7.42±0.07	7.58±0.15
Curdlan sausage[b]	25	2.10±0.04	7.08±0.14	6.87±0.15	7.00±0.12
Curdlan-blank sausage[c]	25	1.54±0.02	6.33±0.13	6.12±0.20	6.27±0.08
Control (20% fat)	70	1.14±0.05	6.70±0.15	6.55±0.16	5.86±0.16
Curdlan sausage[b]	70	1.17±0.03	7.06±0.14	6.95±0.16	6.15±0.10
Curdlan-blank sausage[c]	70	0.83±0.04	6.34±0.13	6.23±0.11	5.49±0.14

[a]Values are means ± standard deviations for 5 repeated measurements.
[b]Sausage using curdlan-based fat mimetics containing 3% curdlan, 10% modified starch, and 1% microcrystalline cellulose.
[c]Sausage using fat mimetics containing 10% modified starch, 1% microcrystalline cellulose, and 3% corn syrup solids in place of curdlan.
[d]E_0: Elastic modulus of the Hookean body; E_1: Elastic modulus of the Voigt body; $_1$: Viscosity of the Voigt body; $_N$: Viscosity of the Newtonian body.

Static viscoelasticity of sausage

The pH of the minced pork we used was about 5.7, and its moisture content was about 72%. The fat content of sausages using the fat mimetic was 1.6% and would not qualify for a NLEA nonfat label. The static viscoelasticity of the sausages was evaluated by a creep test (Table 2) using a 4-element model. When measured at 25°C, all viscoelasticity figures of curdlan sausage were smaller than those of the control. The elastic modulus of the Hookean body and the viscosity of the Newtonian body decreased to 70% and 80% of that of the control, respectively. But the same measurements in the reheated curdlan sausage at 70°C resulted in values closer to those of the control. The elastic modulus of the Hookean body is related to the elastic component and solid-like behavior, whereas the viscosity of the Newtonian body is related to the viscous component and fluid-like behavior. Both parameters are thought to be closely related to

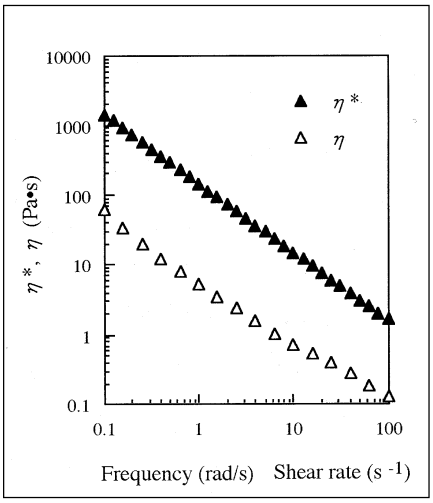

Fig. 4—Relationship between dynamic viscosity and steady shear viscosity of a 3% curdlan aqueous suspension. Aqueous suspension of curdlan prepared by dispersing in cold water, then deaerating. Dynamic viscosity measurement from 10^{-1} to 10^2 rad/s was performed at 25°C using a cone and plate (gap 0.05 mm, cone angle 0.04 rad, diameter 50 mm). Steady shear viscosity was also measured at 25°C over the range γ = 0.1–100 s^{-1} using the same cone and plate geometry. η^*: dynamic viscosity; η: steady shear viscosity.

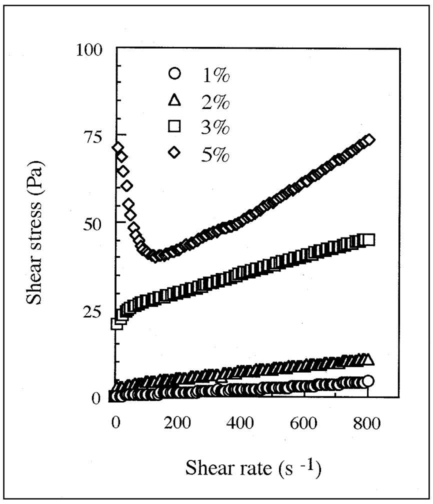

Fig. 5—Flow curves of curdlan aqueous suspensions at various concentrations. Aqueous suspension of curdlan prepared by dispersing in cold water, then deaerating. The measurement was performed at 25°C using cone and plate geometry (cone angle 0.1 rad, diameter 25 mm). The shear rate was increased from 0 to 800 s^{-1} at 400 s^{-1}/min. From the flow curves, yield stress was calculated by Casson's equation.

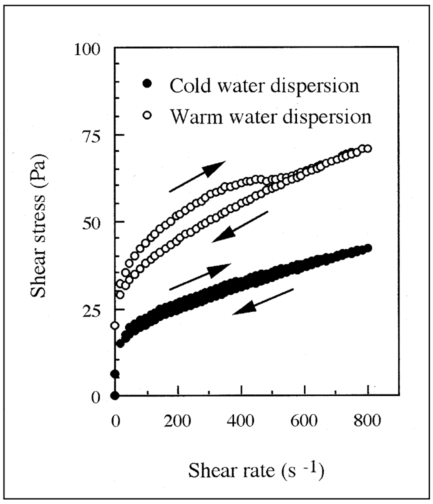

Fig. 6—Thixotropic hysteresis loop of 3% curdlan aqueous suspensions. Aqueous suspensions of curdlan prepared by dispersing in cold water or in warm water, then deaerating. The measurement was performed at 25°C using the same geometry as for Fig. 5. The shear rate was increased from 0 to 800 s^{-1} at 400 s^{-1}/min, and then decreased from 800 to 0 s^{-1} at the same speed.

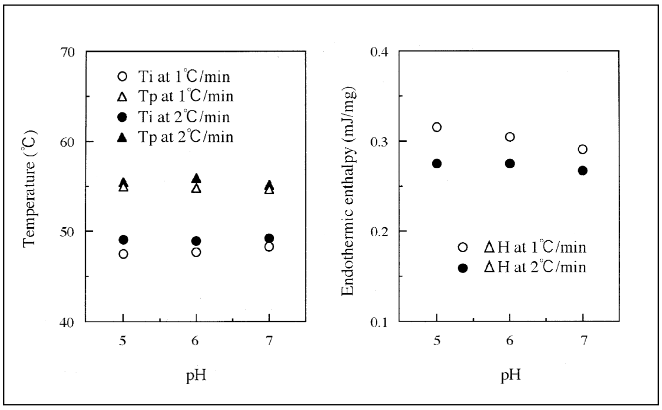

Fig. 7—Effects of pH on differential scanning calorimetry characteristics of a 3% curdlan aqueous suspension. Aqueous suspension of curdlan prepared by dispersing in cold water, then deaerating. Temperature was raised from 5 to 100°C at 1°C/min or 2°C/min. T_i: endothermic incipient temperature; T_p: endothermic peak temperature; ΔH: endothermic enthalpy change.

texture according to Sato et al. (1995). The Hookean elastic modulus is closely related to hardness, whereas the Newtonian viscosity is closely related to adhesiveness. The parameters are also related to the inner structure of a food (Ma et al., 1996). Also, in comparison with curdlan-blank sausage, curdlan was effective especially for the increase in the elastic modulus, due to the structure or yield stress of curdlan aqueous suspensions (Fig. 3, 5). The comparison with nonfat sausage using some popular fat replacing ingredients, which were carbohydrate-based, maltodextrin-based or modified starch+gum-based, was also conducted. The results showed that the Hookean elastic modulus of nonfat sausage using maltodextrin-based fat replacers at 25°C was almost the same as that of curdlan sausage (2.02×10^5 N/m^2). However, both its elastic modulus at 70°C (0.92×10^5 N/m^2) and the Newtonian viscosity (6.65×10^7 Pa·s at 25°C and 5.59×10^7 Pa·s at 70°C) were a little lower than those of curdlan sausage. The results also showed that the Newtonian viscosity of nonfat sausage using modified starch+gum-based fat replacers at 25°C was almost the same as that of curdlan sausage (6.99×10^7 Pa·s). However, both its viscosity at 70°C (5.72×10^7 Pa·s) and the Hookean elastic modulus (1.59×10^5 N/m^2 at 25°C and 0.77×10^5 N/m^2 at 70°C) were a little lower than those of curdlan sausage. Therefore, the viscoelastic figures of curdlan sausage were closest to those of controls in comparison with the other nonfat sausages, especially when reheated. These results suggest that the texture and the structure of the curdlan sausage become closer to those of the control especially in reheated conditions. The advantage of the curdlan-based fat mimetic system in sausages is that it can replace the entire amount of fat and recreates the rheological properties of full-fat sausages without changing the conventional sausage production procedures.

CONCLUSIONS

CURDLAN WAS AN EFFECTIVE INGREDIENT NOT ONLY AS A QUALITY improver in sausage but also as a fat mimetic. A nonfat sausage using a curdlan-based fat mimetic, comprised of three ingredients including curdlan, was prepared and evaluated by static viscoelasticity measurement. Viscoelastic properties of the nonfat sausage with the curdlan-based fat mimetic system were very close to those of the control (20% fat), especially when reheated.

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