IHC 2008

9th International Hydrocolloids Conference
15th to 19th June 2008
Rasa Sentosa Resort, Singapore

19 June 2008

To Whom It May Concern

Dear Sir/Mdm,

**Re: 9th International Hydrocolloids Conference 2008, 15-19 June 2008, Singapore**

This is to certify that **Reza Farhoosh** of **Ferdowsi University of Mashhad** has attended the **9th International Hydrocolloids Conference 2008 (IHC)**, held from 15 to 19 June 2008 at the **Rasa Sentosa Resort, Singapore**.

He has also presented the following poster at the conference:

Poster Code: P-056
Title: A Comparative Study on Time-Independent Rheological Behavior of Saleps, Carboxymethyl Cellulose and Guar Gum as a Function of Concentration and Temperature

Yours sincerely,

Stephan
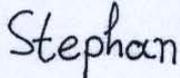
Prof. Stefan Kasapis
General Chair
IHC Organizing Committee

IHC 2008
9th International Hydrocolloids Conference
15 to 19 June 2008, Singapore

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P-055 – Poster

Effect of Extraction Methods on Yield, Purity and Viscosity of Mucilage Extracted from Qodume Shirazi Seed (*Alyssum Homolocarpum*)

Arash KOOCHEKI, Seyed A. MORTAZAVI, Fakhri SHAHIDI, Seyed M. A. RAZAVI, Rasoul KADKHODAEE and Jafar M. MILANI
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Alyssum is a genus of about 100-170 species of flowering plants in the family Brassicaceae, native to Egypt, Arabia, Iraq, Iran and Pakistan. The seeds are known to contain a large amount of mucilaginous substance and have been used as a traditional medicine in Iran. In addition, foods fortified with Alyssum homalocarpum seed gum may be well accepted by the consumer since there is well-established knowledge of medicinal uses of these seeds. Effect of different extraction conditions on extraction yield, apparent viscosity and protein content during extraction of Qodume Shirazi seed gum was investigated. Extraction temperature (25–85°C), pH (4-10) and water to seed ratio (20:1-60:1) were the factors investigated with respect to apparent viscosity, extraction yield and protein content. It was found that increase in pH of extraction resulted in reduction of apparent viscosity but increase in water: seed ratio slightly increased the apparent viscosity. As temperature increased, the apparent viscosity increased slightly. Increase in temperature and water: seed ratio caused an increase in the yield wile pH had no significant effect. It was clear that protein content in the gum increased with the increase in temperature and water:seed ratio.

P-056 – Poster

A Comparative Study on Time-independent Rheological Behavior of Saleps, Carboxymethyl Cellulose and Guar Gum as a Function of Concentration and Temperature

Reza FARHOOSH, Seyed M. A. RAZAVI and Alireza RIAZI
Ferdowsi University of Mashhad, Iran

Rheological properties of palmate-tuber salep (PTS) (2, 3, 4, and 5% w/w) and rounded-tuber salep (RTS) (4, 5, 6, and 7% w/w) were compared to carboxymethyl cellulose (CMC) (1, 1.5, 2, and 3% w/w) and guar gum (0.75, 1, 1.5, and 2% w/w) at four temperatures (5, 25, 45, and 65 °C). Samples were subjected to a programmed shear rate increasing from 0 to 300 s^{-1} in 3 min using a rotational viscometer. The power law model well described the rheological behavior of hydrocolloid solutions. At all concentrations and temperatures, the flow curves of all hydrocolloids showed a shear-thinning behavior. The power law model parameters (k and n values) for all hydrocolloids were dependent to changes in concentration and temperature. A power model was used to evaluate the concentration effect on apparent viscosity (50 s^{-1}). The concentration dependency of apparent viscosity for saleps was higher than that of CMC and guar gum, respectively. This dependency increased as temperature increased. Temperature dependency of the apparent viscosity for hydrocolloid solutions was successfully described by the Arrhenius model. The highest and lowest temperature dependencies of apparent viscosity were belong to PTS

and CMC, and guar gum, respectively. RTS solutions had an intermediate temperature dependency. This dependency decreased as concentration increased.

P-057 – Poster

Emulsifying Properties of Modified Malva Nut Gum with Different Protein Content

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Dry seed of Malva nut (*Scaphium macropodum* Beaum.) can be hydrated in water and readily swell into heat stable gel. The alkaline extracted gum fraction has been characterized[1] to contain about 8.4% protein and 62% carbohydrates which are mainly arabinose, galactose and rhamnose. Our investigations were to evaluate the effect of different treatments of Mulva nut gum on its protein content and emulsifying properties. Comparison of emulsifying properties of different treated Mulva nut gum with gum arabic, guar gum and xanthan gum were made.

Malva nut powder was suspened with water, 0.02 M HCl, 0.1% (w/v) pepsin in 0.02M HCl, 0.01M Phosphate buffer, 0.1% (w/v) bromelain in 0.01 M phosphate buffer at 40°C for various times up to 24 h, neutralized, filtered and dried at 60°C. Malva nut powders and treated samples were separately solubilized with 0.05 M NaOH at 40°C for 16 h, neutralized, vacuum evaporated, freeze-dried and grinded to powder. Total carbohydrate, total phenolics, galacturonic acid content (m-hydroxydiphenyl method), protein content (micro Kjeldahl method) were analyzed. Different Mulva nut gum dispersions in water (0.5% w/v) was evaluated for its emulsifying properties in corn oil emulsion (1:10 oil:water phase). Emulsifying capacity, emulsion heated-stability, and emulsion storage-stability was determined by centrifugation and storage time, surface tension by Du Nouy ring, droplet size by Axiolab Carl Zeiss light microscope, and viscosity by Brookfield. It was found that at 16 h 0.02M HCl, and pepsin treated was equally effective in reduction of about 39.5 % protein content (dry basis) whereas phosphate buffer, bromelain, and water treated were about 28.3% effectiveness. Despite differences in protein content, the emulsifying capacity, emulsion heated-stability of the gum from Malva nut powder (MG), water treated (WMG), and 0.02M HCl treated (AMG) were not significantly differences. However, AMG had significantly (p<0.05) higher viscosity which resulted in higher emulsion storage-stability than MG and WMG. At same concentration AMG was about 2.6 times lower in viscosity, but exhibited higher (p<0.05) emulsion heated-stability and about the same emulsifying capacity as commercial guar gum. Lower emulsion storage-stability of AMG than guar gum and xanthan gum was primarily due to lower gum viscosity. When compare to gum arabic (similar arabinogalactan-rich with arabinogalactan-protein nature) AMG had about 15.6 times higher in viscosity, 1.5 times higher (p<0.05) in emulsion heated-stability, 2 times higher in emulsifying capacity, 3 times higher in emulsion storage-stability than commercial gum arabic.

A Comparative Study on Rheological Behavior of Saleps, CMC and Guar Gum as a Function of Concentration and Temperature

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Summary

Rheological properties of palmate-tuber salep (PTS) (2, 3, 4, and 5% w/w) and rounded-tuber salep (RTS) (4, 5, 6, and 7% w/w) were compared to carboxymethyl cellulose (CMC) (1, 1.5, 2, and 3% w/w) and guar gum (0.75, 1, 1.5, and 2% w/w) at four temperatures (5, 25, 45, and 65 °C). Samples were subjected to a programmed shear rate increasing from 0 to 300 s^{-1} in 3 min using a rotational viscometer. The power law model well described the rheological behavior of hydrocolloid solutions. At all concentrations and temperatures, the flow curves of all hydrocolloids showed a shear-thinning behavior. The power law model parameters (k and n values) for all hydrocolloids were dependent to changes in concentration and temperature. A power model was used to evaluate the concentration effect on apparent viscosity (50 s^{-1}). The concentration dependency of apparent viscosity for saleps was higher than that of CMC and guar gum, respectively. This dependency increased as temperature increased. Temperature dependency of the apparent viscosity for hydrocolloid solutions was

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successfully described by the Arrhenius model. The highest and lowest temperature dependencies of apparent viscosity were belong to PTS and CMC, and guar gum, respectively. RTS solutions had an intermediate temperature dependency. This dependency decreased as concentration increased.

Introduction

Salep is a flour milled from the dried tubers of certain wild terrestrial orchids (Kaya & Tekin, 2001) and has been used for many years for its nutritive and demulcent properties (Ktistis & Georgakopoulos, 1991). Besides giving the desired aroma and flavor to product, it also serves as a thickening and stabilizing agent when added into formulation (Kayacier & Dogan, 2006). Salep has been used in medicines, drinks and ice-creams (Lange, 1998). Salep varieties grown in Iran represent two forms, the one with branched or palmate, and the other, with rounded or unbranched tubers. The palmate- and rounded-tuber saleps (PTS and RTS) were known to be a valuable source for glucomannan (22-58%). They also contain starch (1.7-6.2%), nitrogenous substance (3.1-7.3%), lipids (~2%), moisture (~13%), and ash (2.1-3.8%) (Farhoosh & Riazi, 2006).

Carboxymethyl cellulose (CMC) is the most important water-soluble cellulose derivative, with many applications in food industry and in cosmetics, pharmaceuticals, detergents, etc. (Olaru et al., 1998). It is widely used to viscosify various food products such as dairy products, frozen desserts, jellies, cake mixes, salad dressings, etc (Zorba & Ova, 1999). CMC is formed by its reaction with sodium hydroxide and chloroacetic acid. It has a number of sodium carboxymethyl groups (CH_2COONa), introduced into the cellulose

molecule, which promote water solubility. Among all the polysaccharides, CMC is easily available and it is also very cheap (Biswal & Singh, 2004).

Guar gum, obtained from the endosperm of the Indian cluster bean *Cyamopsis tetragonoloba* (L.) Taub., is a water-soluble polysaccharide composed primarily of mannose and galactose sugars (Dea & Morrison, 1975). The ability of guar gum to act as an efficient water thickening agent at low concentrations, its relatively low cost, and its edibility make it commercially attractive. The food industry makes widespread use of guar gum as a thickener for ice cream, sauces, and salad dressings (Kramer et al., 1987).

Hydrocolloids are widely used in various food products to create proper rheological characteristics. The rheological behavior of hydrocolloids considerably affects the quality of final product, mostly textural attributes. In our country, saleps are used individually or interchangeably with CMC or guar gum in many food applications, but there is no rheological data recorded in literature concerning the comparison of saleps with the two other ones. Hence, the aim of this study was to compare the rheological properties of saleps with CMC and guar gum as a function of concentration and temperature.

Materials and methods

Materials

Palmate-tuber salep (PTS) and rounded-tuber salep (RTS) were purchased from a supplier in Kordestan, Iran, and were prepared as a yellowish color powder according to the method described by Farhoosh & Riazi (2006). Samples of guar gum (Higum, 4500F, Rhodia) and CMC (Sunrose, F50MC, Nippon, Chemicals Co., Ltd) were obtained from different

sources. All chemicals and solvents were of analytical reagent grade and purchased from Sigma-Aldrich (St. Louis, MO) and Merck (Darmstadt, Germany) companies.

Preparation of solutions

Four levels of concentration were employed: PTS (2, 3, 4, and 5% w/w), RTS (4, 5, 6, and 7% w/w), guar gum (0.75, 1, 1.5 and 2% w/w), and CMC (1, 1.5, 2, and 3% w/w). The solutions were prepared by dispersing the powders in deionized water using a high speed blender for 15 min at room temperature. Only for salep solutions, the procedure was followed by heating at 90 °C for 10 min in a water bath. Finally, they were homogenized at a low speed blender for 1 min, and then were cooled. All sample solutions were prepared in duplicate.

Rheological measurements

Rheological evaluations were performed using a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) equipped with a heating circulator (Julabo, Model F12-MC, Julabo Labortechnik, Germany). Appropriate measuring spindles (C14, C25, C30) were used during viscosity measurements according to the viscosity of dispersion. Prepared samples were loaded into the cup and allowed to equilibrate for 10 min at desired temperature (5, 25, 45 and 65 °C) and were subjected to a programmed shear rate logarithmically increasing from 0 to 300 s^{-1} in 3 min.

Data analysis

The power law model was used to describe the rheological properties of solutions. The flow behavior index (n) (dimensionless) and consistency coefficient (k) (Pa s^n) values were obtained by fitting the power law model to the shear stress (τ) (Pa) versus shear rate (γ) (s^{-1}) data.

$$\tau = k\,\gamma^{\,n} \tag{1}$$

The apparent viscosity (η_a) (Pa s) was computed at a shear rate of 50 s^{-1} as the ratio of τ/γ using the Eq. (1). The low shear rate of 50 s^{-1} was selected because it has been reported as an effective oral shear rate (Morris, 1983). The concentration dependency of apparent viscosity was evaluated using the Eq. (2).

$$\ln \eta_a = \ln a + b \ln C \tag{2}$$

where a and b are the constants of the equation, and C is concentration (%) (Marcotte et al., 2001).

The temperature dependency of apparent viscosity was evaluated by applying an Arrhenius model (Grigelmo et al., 1999).

$$\ln \eta_a = \ln A + (E_a/RT) \tag{3}$$

where A is the frequency factor (Pa s^n), E_a is the activation energy (kJ/mol), R is the universal gas constant (kJ/mol K), and T is the absolute temperature (K).

Results and discussion

Typical flow curves for hydrocolloid solutions evaluated at 25 °C are shown in Fig. 1. At all concentrations and temperatures, the flow curves of all hydrocolloids showed a pseudoplastic (shear-thinning) behavior ($n<1$); that is, the apparent viscosity of all hydrocolloid solutions decreased with increasing shear rate. Such behavior has already been reported for saleps (Farhoosh & Riazi, 2006), guar gum (Rayment et al., 1995), and CMC

(Togrul & Arslan, 2003). The decrease in viscosity as the shear rate was increased has been related to the increased alignment of constituent molecules of the tested system (Rha, 1975).

The rheological parameters obtained based on the power law model (Eq. (1)) for hydrocolloids, and the determination coefficients (r^2) are presented in Tables 1-4. At the range of shear rate studied, the power law model appeared to be suitable for describing the flow behavior of hydrocolloid solutions. The determination coefficients, for most cases, were higher than 0.98 with higher concentrations and temperatures showing slightly lower values.

For all hydrocolloids, an increase in concentration was accompanied with an increase in pseudoplasticity, shown by a decrease in values of the flow behavior index (Tables 1-4), a measure of the departure from Newtonian flow. The smaller the n values the greater the departure from Newtonian behavior (Chhinnan et al., 1985). Szczesniak and Farkas (1962) showed that gum solutions with a high n value tend to feel slimy in the mouth. When high viscosity and a good mouth feel characteristics are desired, the choice should be a gum system having a low n value (Marcotte et al., 2001). The flow behavior indices showed an increasing trend with temperature which indicated that the hydrocolloid solutions were tending to be closer to Newtonian flow at higher temperatures. Comparatively, the flow behavior index of PTS varied between 0.265 (5%, 5 °C) and 0.768 (2%, 65 °C) whereas for RTS it was situated between 0.233 (7%, 5 °C) and 0.625 (4%, 65 °C). The lowest values (0.093-0.164) of flow behavior index were observed for guar gum (2%) at all temperatures. The flow behavior indices of CMC were the nearest values to those of PTS within the range of concentration and temperature levels studied. The flow behavior indices of 2% PTS were nearly similar to those of 1% CMC at all the same temperatures. There was a more pseudoplasticity for PTS than RTS at the same concentration (4%) and temperatures. At the same concentration (2%) and all temperatures, the lowest flow behavior indices were belong to guar gum, and then CMC and PTS, respectively.

At all temperatures, the consistency coefficient of all hydrocolloids increased with increasing concentration (Tables 1-4). The higher solid contents generally cause an increase in the viscosity resulting from mainly molecular movements and interfacial film formation (Bhattacharya et al., 1992; Maskan & Gogus, 2000). All consistency coefficients decreased with increasing temperature. As temperature increases, thermal energy of the molecules increases and molecular distances develop due to reduction of intermolecular forces (Hassan & Hobani, 1998; Togrul & Arslan, 2004). The value of consistency coefficient for PTS, RTS, CMC, and guar gum ranged from 0.534 (2%, 65 °C) to 256.027 (5%, 5°C), 1.436 (4%, 65 °C) to 115.643 (7%, 5°C), 0.342 (1%, 65 °C) to 162.841 (3%, 5 °C), and 2.132 (0.75%, 65 °C) to 137.644 (2%, 5 °C), respectively. At similar concentrations and temperatures, PTS solutions were much more consistent than RTS solutions, which this attributed to their different chemical composition, mainly glucomannan and starch contents (Farhoosh & Riazi, 2006). The consistency coefficient of guar gum solutions was very higher than that of PTS solutions at the same concentration (2%) and temperatures. Under the same conditions, CMC solutions had intermediate values.

For all samples, the apparent viscosity at 50 s^{-1} increased with increasing concentration. Table 5 shows the regression equation parameters a and b (Eq. (2)) for apparent viscosity. The determination coefficients obtained were high indicating that the equation adequately describes the associated variability. The parameter a decreased with increasing temperature for all hydrocolloids. The magnitude of concentration effect on the apparent viscosities, which is evidenced by the b values, for saleps was nearly the same and higher than that of the other hydrocolloids at all the same temperatures. At all the same temperatures, CMC solutions had b values higher than those of guar gum solutions. The b values increased as temperature increased (Fig. 2) indicating a higher dependency or sensitivity of apparent viscosity on concentration. On the basis of the slopes calculated in Fig.

2, the magnitude of temperature effect on the *b* values for hydrocolloids was according to the order of PTS > RTS > CMC > guar gum.

The apparent viscosity for hydrocolloid solutions in relation with temperature generally obeyed the Arrhenius model (Table 6). Frequency factors (A), activation energies (E_a) and determination coefficients are listed in Table 6. For all samples, the apparent viscosity decreased with increasing temperature. The frequency factors increased with increasing concentration for all hydrocolloids. Among the hydrocolloids, guar gum had the lowest E_a values. The PTS and CMC solutions showed the highest values of activation energy indicating a lower resistance at elevated temperatures. RTS solutions had intermediate values of the activation energy. For all hydrocolloids, the activation energies decreased as concentration increased (Fig. 3). This means that the sensitivity of the apparent viscosity to the variations of temperature decreases with increasing concentration. As shown in Fig. 3, the magnitude of concentration effect on the E_a values for hydrocolloids was according to the order of guar gum > RTS > PTS > CMC.

Conclusions

A clearly pseudoplastic behavior was observed at all concentrations and temperatures for all hydrocolloids. The power law model well described the rheological behavior of hydrocolloid solutions. An increase in concentration was accompanied with an increase in pseudoplasticity and consistency. As temperature increased, the hydrocolloid solutions showed a lower consistency and were tending to be closer to Newtonian flow. At similar concentrations and temperatures, PTSs created solutions with pseudoplasticity and consistency more than those of RTSs. Guar gum solutions were more pseudoplastic and

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consistent than CMC solutions, which were in turn more pseudoplastic and consistent than PTS solutions at the same conditions.

Higher hydrocolloid concentrations resulted in an increase of apparent viscosity (50 s^{-1}). The concentration dependency of apparent viscosity for saleps was higher than that of CMC and guar gum, respectively. This dependency increased as temperature increased. The apparent viscosities decreased with increasing temperature. The highest and lowest temperature dependencies of apparent viscosity were belong to PTS and CMC, and guar gum, respectively. RTS solutions had an intermediate temperature dependency. This dependency decreased as concentration increased.

References

Bhattacharya, S., Bhat, K.K. & Raghuver, K.G. (1992). Rheology of Bengal gram cicer arietinum flour suspensions. Journal of Food Engineering, 17, 83-96.

Biswal, D.R. & Singh, R.P. (2004). Characterization of carboxymethyl cellulose and polyacrylamide graft copolymer. Carbohydrate Polymers, 57, 379-387.

Chhinnan, M.S., McWaters, K.H. & Rao, V.N.M. (1985). Rheological characterization of grain legume pastes and effect of hydration time and water level on apparent viscosity. Journal of Food Science, 50, 1167–1171.

Dea, I.C.M. & Morrison, A. (1975). Chemistry and interactions of seed galactomannans. Advances in Carbohydrate Chemistry and Biochemistry, 31, 241-312.

Farhoosh, R. & Riazi, A. (2006). A compositional study on two current types of salep in Iran and their rheological properties as a function of concentration and temperature. Food Hydrocolloid, 21, 660-666.

Grigelmo, N.M., Ibarz, A.R. & Martin, O.B. (1999). Rheology of peach dietary fibre suspensions. Journal of Food Engineering, 39, 91-99.

Hassan, B.H. & Hobani, A.I. (1998). Flow properties of Roselle (Hibiscus sabdariffa L.) extract. Journal of Food Engineering, 35, 459-470.

Kaya, S. & Tekin, A.R. (2001). The effect of salep content on the rheological characteristics of a typical ice-cream mix. Journal of Food Engineering, 47, 59-62.

Kayacier, A. & Dogan, M. (2006). Rheological properties of some gums-salep mixed solutions. Journal of Food Engineering, 77, 261-265.

Kramer, J., Uhl, J.T. & Prudhomme, R.K. (1987). Measurement of the viscosity of guar gum solutions to 50,000 s^{-1} using a parallel plate rheometer. Polymer Engineering and Science, 27, 598-602.

Ktistis, G. & Georgakopoulos, P.P. (1991). Rheology of salep mucilages. Pharmazie, 46, 55-56.

Lange, D. (1998). Europe's Medicinal and Aromatic Plants: Their use, Trade and Conservation. Cambridge: Traffic Europe/International.

Marcotte, M, Hoshahili, A.R.T. & Ramaswamy, H.S. (2001). Rheological properties of selected hydrocolloids as a function of concentration and temperature. Food Research International, 34, 695-703.

Maskan, M. & Gogus, F. (2000). Effect of sugar on the rheological properties of sunflower oil-water emulsions. Journal of Food Engineering, 43, 173-177.

Morris, E.R. (1983). Gums and stabilizers for the food industry. Oxford: Pergamon Press.

Olaru, N., Olaru, L., Stoleriu, A. & Timpu, D. (1998). Carboxymethyl cellulose synthesis in organic media containing ethanol and/or acetone. Journal of Applied Polymer Science, 67, 481-486.

Rayment, P., Ross-Murphy, S.B. & Ellis, P.R. (1995). Rheological properties of guar galactomannan and rice starch mixtures. I. Steady shear measurements. Carbohydrate Polymers, 28, 121-130.

Rha, C. (1975). Theories and principles of viscosity. In C. Rha, Theory, determination and control of physical properties of food materials (pp. 7-24). Dordrecht, The Netherlands: Reidel.

Szczesniak, A. S. & Farkas, E. (1962). Objective characterization of the mouthfeel of gum solutions. Journal of Food Science, 27, 381–385.

Togrul, H. & Arslan, N. (2003). Production of carboxymethyl cellulose from sugar beet pulp cellulose and rheological behaviour of carboxymethyl cellulose. Carbohydrate Polymers, 54, 73-82.

Togrul, H. & Arslan, N. (2004). Mathematical model for prediction of apparent viscosity of molasses. Journal of Food Engineering, 62, 281-289.

Zorba, M & Ova, G. (1999). An improved method for the quantitative determination of carboxymethyl cellulose in food products. Food Hydrocolloids, 13, 73-76.
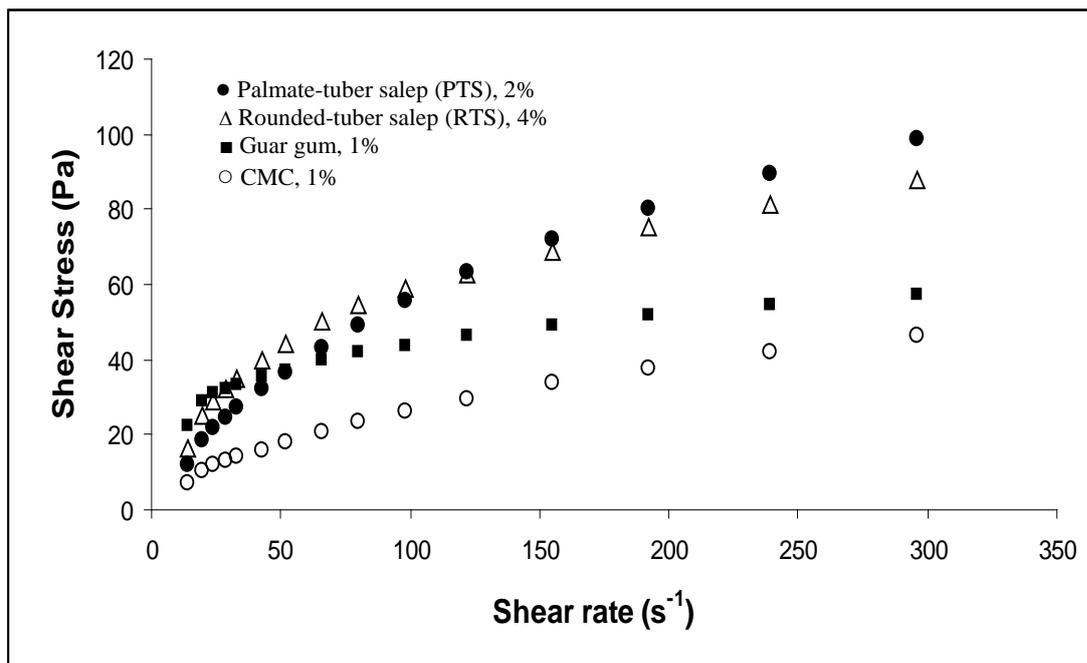
Figure 1 Typical flow behavior of the hydrocolloid solutions at 25 °C.
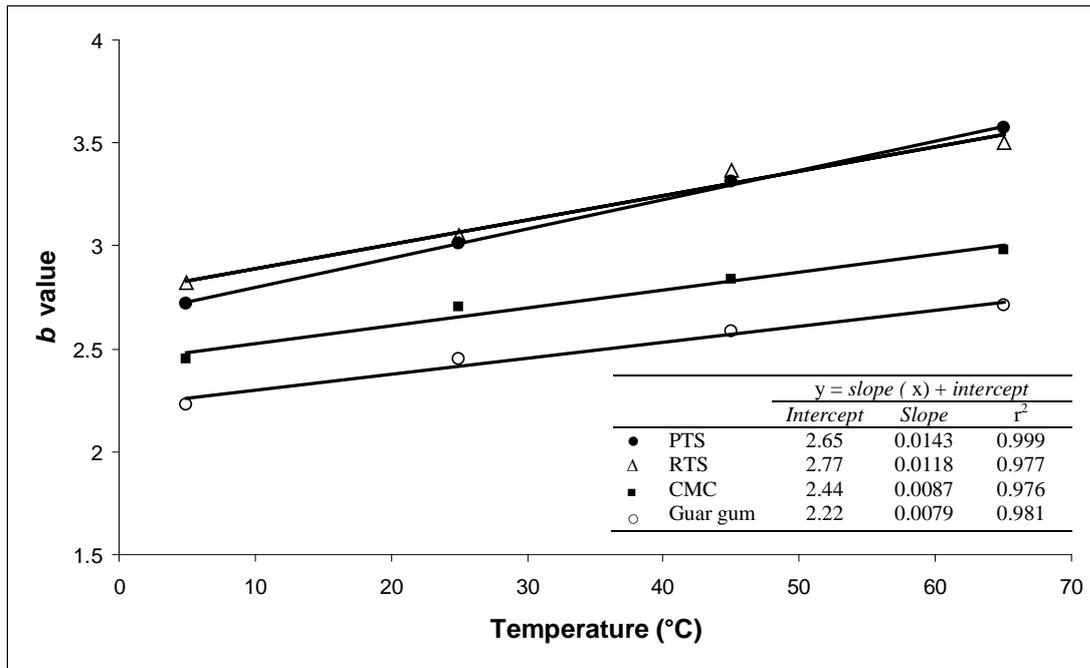
Figure 2 The effect of temperature on the sensitivity of apparent viscosity to the variations of concentration.
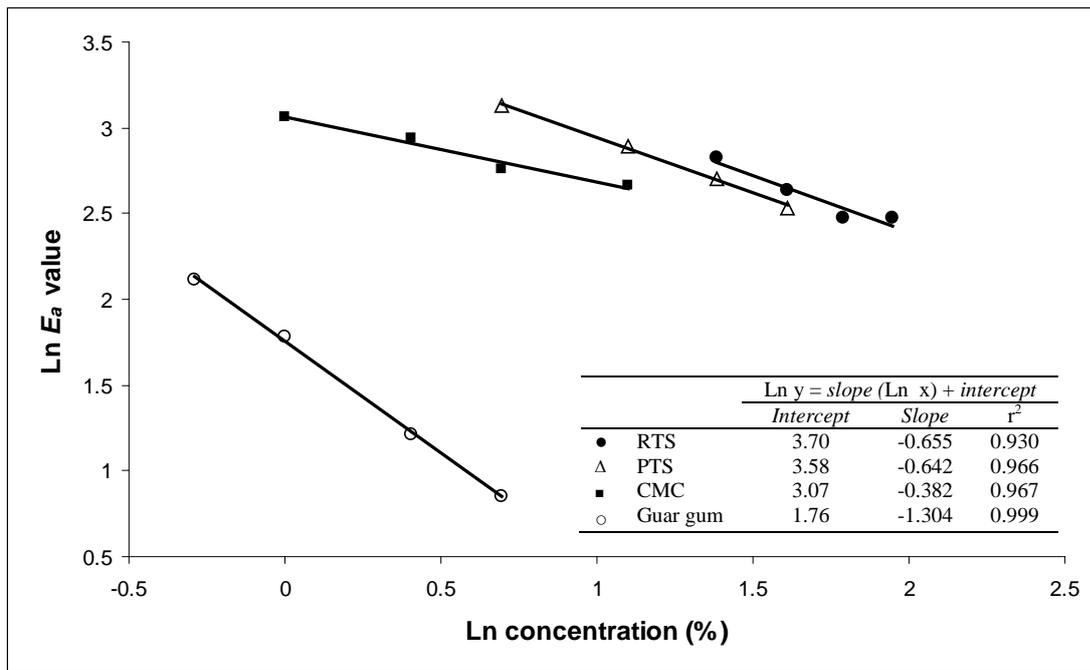
Figure 3 The effect of concentration on the sensitivity of apparent viscosity to the variations of temperature.

Table 1 The power law model parameters for palmate-tuber salep (PTS) solutions at different concentrations and temperatures.

T(°C)	Concentration (%)											
	2			3			4			5		
	$k\ (Pa\ s^n)$	n	r^2	$k\ (Pa\ s^n)$	n	r^2	$k\ (Pa\ s^n)$	n	r^2	$k\ (Pa\ s^n)$	n	r^2
5	8.696±0.342	0.496±0.004	0.989	45.197±0.229	0.380±0.001	0.989	128.062±3.183	0.311±0.005	0.982	256.027±2.653	0.265±0.001	0.966
25	3.499±0.072	0.591±0.000	0.993	20.484±0.042	0.467±0.001	0.992	68.542±4.096	0.381±0.005	0.987	145.060±0.846	0.336±0.001	0.983
45	1.346±0.048	0.685±0.002	0.996	9.620±0.128	0.541±0.002	0.991	35.180±0.823	0.453±0.003	0.991	82.757±1.595	0.401±0.002	0.989
65	0.534±0.013	0.768±0.003	0.998	4.302±0.114	0.621±0.003	0.995	17.565±0.546	0.525±0.004	0.994	44.045±1.123	0.461±0.004	0.990

Table 2 The power law model parameters for rounded-tuber salep (RTS) solutions at different concentrations and temperatures.

T(°C)	Concentration (%)											
	4			5			6			7		
	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2
5	13.774±0.569	0.365±0.005	0.980	35.156±0.401	0.317±0.000	0.972	70.104±0.758	0.263±0.003	0.971	115.643±2.214	0.233±0.003	0.968
25	7.251±0.430	0.443±0.009	0.983	19.111±0.553	0.391±0.002	0.981	39.966±3.125	0.342±0.006	0.976	70.203±0.014	0.303±0.002	0.972
45	3.148±0.039	0.539±0.001	0.986	11.205±0.504	0.439±0.003	0.971	19.836±0.170	0.432±0.003	0.985	37.292±1.595	0.390±0.005	0.978
65	1.436±0.018	0.625±0.001	0.990	4.911±0.473	0.546±0.009	0.987	11.743±0.790	0.483±0.006	0.981	16.009±2.165	0.498±0.019	0.982

Table 3 The power law model parameters for carboxymethyl cellulose (CMC) solutions at different concentrations and temperatures.

T(°C)	Concentration (%)											
	1			1.5			2			3		
	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2	k (Pa s^n)	n	r^2
5	4.254±0.252	0.489±0.006	0.997	18.536±3.943	0.378±0.024	0.992	40.748±1.902	0.346±0.001	0.993	162.841±5.304	0.251±0.002	0.990
25	1.770±0.345	0.567±0.017	0.998	6.943±0.628	0.468±0.010	0.997	24.242±0.273	0.387±0.002	0.994	100.438±4.098	0.285±0.007	0.997
45	0.803±0.042	0.636±0.007	0.998	3.480±0.294	0.526±0.003	0.998	12.219±0.266	0.441±0.002	0.998	61.648±0.523	0.323±0.010	0.992
65	0.342±0.050	0.716±0.018	0.999	2.170±0.336	0.556±0.016	0.999	7.751±0.389	0.466±0.006	0.999	40.188±2.876	0.340±0.006	0.977

Table 4 The power law model parameters for guar gum solutions at different concentrations and temperatures.

	Concentration (%)											
	0.75			1			1.5			2		
T(°C)	$k\ (Pa\ s^{n})$	n	r^{2}	$k\ (Pa\ s^{n})$	n	r^{2}	$k\ (Pa\ s^{n})$	n	r^{2}	$k\ (Pa\ s^{n})$	n	r^{2}
5	6.514±0.286	0.305±0.003	0.993	17.675±0.439	0.231±0.002	0.984	60.109±0.274	0.147±0.005	0.969	137.644±3.660	0.093±0.001	0.941
25	4.494±0.291	0.339±0.004	0.993	12.283±1.065	0.265±0.006	0.986	48.867±1.111	0.176±0.002	0.977	123.141±5.023	0.107±0.003	0.905
45	3.033±0.063	0.382±0.001	0.991	10.611±0.768	0.289±0.005	0.986	41.507±0.265	0.197±0.001	0.961	100.017±7.097	0.137±0.016	0.915
65	2.132±0.031	0.423±0.001	0.990	7.201±0.151	0.330±0.002	0.987	31.573±1.295	0.228±0.005	0.974	83.965±1.027	0.164±0.004	0.942

Table 5 Concentration coefficients (Eq. (2)) for apparent viscosity of the hydrocolloid solutions at 50 s^{-1}.

Sample	Temperature (°C)	a	b	r^2
PTS	5	0.192	2.72	0.998
	25	0.090	3.01	0.998
	45	0.040	3.31	0.999
	65	0.018	3.57	0.998
RTS	5	0.025	2.82	0.995
	25	0.013	3.05	0.997
	45	0.005	3.37	0.994
	65	0.003	3.50	0.987
CMC	5	0.577	2.45	0.999
	25	0.307	2.70	0.997
	45	0.181	2.84	0.998
	65	0.110	2.98	0.999
Guar gum	5	0.819	2.23	0.999
	25	0.684	2.45	1.000
	45	0.600	2.58	0.996
	65	0.502	2.71	0.999

Table 6 Temperature coefficients (Eq. (3)) for apparent viscosity of the hydrocolloid solutions at 50 s^{-1}.

Sample	Concentration (%)	A (Pa s^n)	E_a (kJ/mol)	r^2
PTS	2	6.769×10^{-5}	22.744	0.992
	3	1.635×10^{-3}	18.087	0.992
	4	1.436×10^{-2}	14.863	0.989
	5	6.361×10^{-2}	12.624	0.983
RTS	4	8.690×10^{-4}	16.807	0.982
	5	6.019×10^{-3}	13.993	0.982
	6	2.324×10^{-2}	11.934	0.986
	7	3.560×10^{-2}	11.887	0.949
CMC	1	5.504×10^{-5}	21.396	0.996
	1.5	4.198×10^{-4}	18.965	0.995
	2	3.463×10^{-3}	15.775	0.992
	3	1.756×10^{-2}	14.343	0.993
Guar gum	0.75	1.151×10^{-2}	8.312	1.000
	1	6.520×10^{-2}	5.928	0.949
	1.5	4.787×10^{-1}	3.360	0.920
	2	1.392	2.352	0.967