Food Sci. Biotechnol. Vol. 16, No. 3, pp. 496 ~ 499 (2007)

Food Science and Biotechnology

RESEARCH NOTE

Effect of Storage Temperature on Dynamic Rheological Properties of Hot Pepper-Soybean Pastes Mixed with Guar Gum and Xanthan Gum

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Abstract Dynamic rheological properties of hot pepper-soybean paste (HPSP) samples mixed with guar gum and xanthan gum were evaluated at different storage temperatures (5, 15, and 25°C) by using a dynamic rheometer. Magnitudes of storage modulus (G'), loss modulus (G"), and complex viscosity (η^*) in the HPSP-gum mixtures increased with an increase in storage temperature from 5 to 25°C. After 3-month storage at 5 and 15°C there were no significant changes in dynamic rheological properties. The increase in dynamic moduli (G', G", and η^*) with storage temperature is less pronounced at HPSP-xanthan gum mixtures in comparison to HPSP-guar gum mixtures. The slopes of G' (0.16-0.18) of HPSP-guar gum mixtures at 3-month storage were much higher than that (0.10) at 0-month storage, indicating that the elastic properties of the HPSP-guar gum mixtures can be decreased after 3-month storage. However, there were not much differences between the slopes of G' in HPSP-xathan gum mixtures. Xanthan gum was observed to be better structure stabilizer for HPSP during storage.

Keywords: hot pepper-soybean paste, guar gum, xanthan gum, storage temperature, rheology, dynamic modulus

Introduction

Hot pepper-soybean paste (HPSP), *kochujang*, is a fermented seasoning sauce popular in Korea. HPSP is a food dispersion that is composed of solid particles (red pepper and soybean powders) dispersed in a continuous medium (1). It also has a homogeneous texture with a stable network structure due to the gelatinization of starch through processing and the particle-particle interaction of raw materials during fermentation (2). From a consumer point of view, the viscosity of commercial HPSP product is an important attribute and its quality is often determined by the change of viscosity which can be occurred through a long period of storage. HPSP obtains its viscosity mainly from glutinous rice starch paste mixed with red pepper powder. Therefore, in order to evaluate the quality of HPSP, it is necessary to understand its rheological properties during storage. In particular, reliable rheological data are necessary for ensuring product acceptability as the products with undesirable textural characteristics are unacceptable from consumer. Many researchers have studied the rheological properties of HPSP products as affected by fermentation time (3), fermentation temperature (4), the particle size of red pepper powder (5), the concentration of HPSP (1), the type of gum (6), and the concentration of xanthan gum (7). In contrast, little information is available on the rheological properties of HPSP as affected by storage conditions. During storage, HPSP tends to lose its rheological properties due to hydrolysis and syneresis (serum separation) which lower its quality and sensory acceptance. These disadvantageous phenomena can be reduced by the addition of gums to HPSP, as described previously (6, 7).

Gums, which are used as functional ingredients in the food industry, play an important role in modifying and controlling the rheological properties of food products. The change in viscosity occurs due to the high molecular weight polymeric nature of the gums and the interactions between polymer chains when gums are dissolved or dispersed (8). The gums are widely used in food dispersions, such as tomato ketchup (9, 10), sauces (11), and fruit fillings (12), in order to improve their rheological characteristics and shelf life. In earlier studies by Choi and Yoo (6, 7), it has been known that the addition of gum to HPSP can be used to improve and control the dynamic rheological properties of HPSP using nondestructive dynamic oscillatory measurements. The dynamic rheometry for small-deformation oscillatory measurements can be used to observe the rheological properties of HPSP more precisely without causing damage to its internal network structure. However, no attempt has been made to study the effect of storage temperature on the dynamic rheological properties of HPSP mixed with gums. Therefore, understanding rheological properties of HPSP-gum mixtures at different storage temperatures will lead to improvements in the formulation of HPSP products. In the present study the guar gum and xanthan gum are selected among the gums (guar gum, xanthan gum, CMC, HPMC, tara gum, etc.) dissolved in ambient temperature because they have been widely used in the food industry.

The main objectives of the present study were to investigate the effect of storage temperature on the dynamic rheological properties of HPSP mixed with guar gum and xanthan gum using dynamic oscillatory measurements, and to compare the dynamic theological properties of HPSP-guar gum and HPSP-xanthan gum mixtures.

Materials and Methods

Materials and preparation of hot pepper-soybean paste (HPSP) For the preparation of traditional fermented HPSP glutinous rice flour, malt flour, *meju* flour, red pepper powder, and salt were purchased in a local supermarket.

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Received January 24, 2007; accepted March 22, 2007

Malt flour was soaked in water for 1 hr, cooked at 60°C for 1 hr, and filtered for the preparation of malt extract. The mixture of glutinous rice flour and malt extract was heated at 60°C for 90 min and mixed with other ingredients (*meju* flour, red pepper powder, and salt) to obtain HPSP. The recipe for the preparation of HPSP was 23% glutinous rice flour, 8.7% *meju* flour, 17.3% red pepper powder, 8.2% salt, and 8.5% malt flour. Predetermined amount of water was added to adjust the final moisture level of HPSP sample to 58%. The HPSP sample was immediately portioned into two samples of 300 g each. The guar gum and xanthan gum at 0.3% concentration were then added into each sample and mixed for 5 min at 1,000 rpm using a mixer having a rotational blade with a diameter of 50 mm (type Z-1000; Eyela, Tokyo, Japan). HPSP samples were poured into the plastic jars and incubated at 25°C for 12-week fermentation. Finally, the HPSP-gum mixture sample (0-month storage) was portioned into three samples of 100 g each and then stored at different temperatures (5, 15, and 25°C) for 3 months to measure the dynamic rheological properties of HPSP samples mixed with gums after 3-months storage as a function of storage temperature. These conditions were chosen because HPSP products are usually stored at refrigeration or room temperatures that varies between 5 and 25°C and there were also clear changes in color or flavor of the HPSP-gum mixture samples after 3-months storage.

Rheological measurements A TA rheometer (AR 1000; TA Instruments, New Castle, DE, USA) was used to conduct steady and dynamic shear experiments at 25°C using a parallel plate system (4 cm diameter) at gap 1,000 μm. Sample was allowed to rest for 5 min before rheological measurements were conducted following the loading of the sample on the rheometer plate.

Dynamic shear data were obtained over the range of 0.63-62.8 rad/sec at strain of 3%. Linear viscoelastic range was determined for each sample from stress sweeps at 6.28 rad/sec. Rheometer Data Analysis Software (version VI.1.76) was used to calculate storage modulus (G'), loss modulus (G"), complex viscosity (η*), and tan δ (the ratio of G"/G') as a function of frequency. All experiments were conducted in triplicate. Results are reported as the average of the three measurements.

Results and Discussion

Figure 1 shows changes in storage (or elastic) modulus (G') and loss (or viscous) modulus (G") of HPSP samples mixed with guar gum and xanthan gum as a function of the frequency (ω) at different storage temperatures (5, 15, and 25°C) after 3-months storage. G' is a measure of the energy that is stored in the material, while G" is a measure of the energy that is lost as viscous dissipation. The magnitudes of G' and G" were found to increase with an increase in ω, and G' was much higher compared to the G" at all values of ω with the small frequency dependency confirming the viscoelastic nature of HPSP. Similar trend was reported with other HPSP samples mixed with gums (6, 7).

Table 1 shows G', G", η*, and tan δ values at 6.28 rad/sec for the HPSP-gum mixtures at 0-month storage and those with different storage temperatures (5, 15, and 25°C) at 3-month storage. From the dynamic rheological data, it was found that the HPSP-gum mixtures at 3-month storage exhibited weak gel-like behavior because the slopes (slopes of G'= 0.14-0.18 kPa·sec; slopes of G"= 0.20-0.23 kPa·sec) are positive (Table 2) and the magnitudes of G' (2.91-9.39 kPa) are higher than those of G" (1.35-4.38 kPa). The G"/G' ratio (tan δ) is greater than 0.1, meaning that a sample is a weak gel which is between the structures of a concentrated biopolymer solution and a true gel (13). Therefore, it could be characterized as a typical viscoelastic gel of food dispersions. For all the HPSP samples, tan δ values are in the range of 0.46-0.48, indicating the dominance of elastic properties over viscous ones and also a typical behavior of weak gel. It was found that the G' was much higher compared to the G" throughout the frequency range employed confirming the viscoelastic nature of HPSP-gum mixtures. The dynamic moduli (G', G", and η*) of all HPSP-gum mixtures at 3-month storage were higher than those at 0-month storage. Higher dynamic moduli at 3-month storage can mainly be related to the particle aggregation as well as the retrogradation of starch developed through a long period

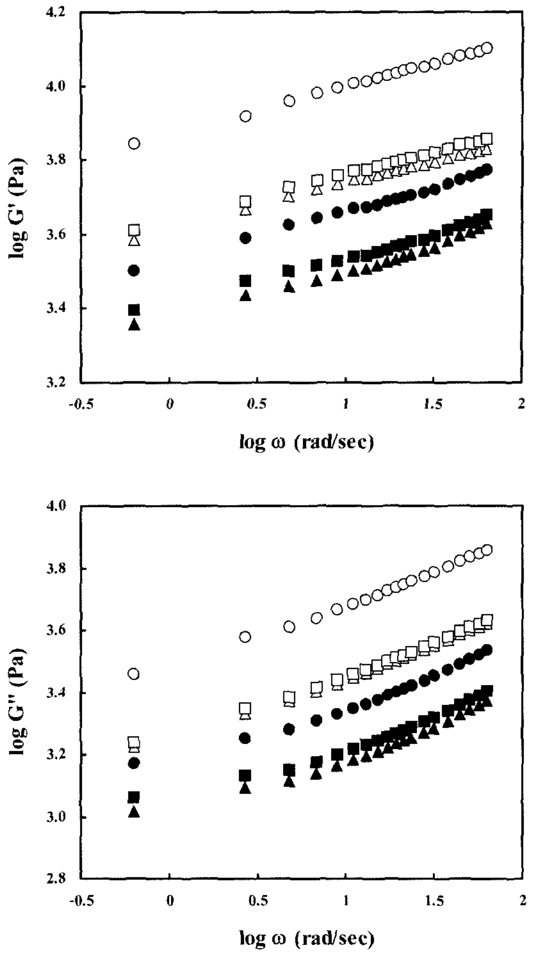

Fig. 1. Plot of log G' and log G" vs. log ω for HPSP samples mixed with guar gum and xanthan gum at different storage temperature. (△, ▲) 5°C; (□, ■) 15°C; (○, ●) 25°C. Open symbol, guar gum; closed symbol, xanthan gum.

Table 1. Storage modulus (G'), loss modulus (G"), complex viscosity (η*), and tan δ at 6.28 rad/sec of HPSP-gum mixtures at different storage temperatures[1)]

Sample	Storage time	Storage temp. (°C)	G' (kPa)	G" (kPa)	η*(kPa·sec)	Tan δ
Guar gum	0-month		4.09±0.00	1.93±0.01	0.72±0.00	0.47±0.00
	3-month	5	5.11±0.09	2.45±0.05	0.90±0.01	0.48±0.00
		15	5.54±0.10	2.59±0.04	0.97±0.01	0.47±0.00
		25	9.39±0.04	4.38±0.07	1.64±0.05	0.47±0.01
Xanthan gum	0-month		2.78±0.00	1.19±0.00	0.48±0.00	0.43±0.00
	3-month	5	2.91±0.04	1.35±0.02	0.51±0.00	0.47±0.00
		15	3.20±0.03	1.45±0.04	0.56±0.08	0.46±0.01
		25	4.30±0.01	2.01±0.00	0.75±0.00	0.47±0.00

[1)] Values are mean±SD of triplicate measurements.

Table 2. Slope values of log G' and log G" vs. log ω curve of HPSP-gum mixtures at different storage temperatures[1)]

Sample	Storage time	Storage temp. (°C)	Slope of G' (kPa·sec)	R^2	Slope of G" (kPa·sec)	R^2
Guar gum	0-month		0.10±0.00	0.99	0.21±0.00	0.99
	3-month	5	0.16±0.00	0.99	0.20±0.00	0.99
		15	0.16±0.00	0.99	0.20±0.00	0.99
		25	0.18±0.00	0.99	0.21±0.00	0.99
Xanthan gum	0-month		0.15±0.00	0.99	0.23±0.00	0.99
	3-month	5	0.14±0.00	0.99	0.22±0.00	0.98
		15	0.14±0.00	0.99	0.21±0.00	0.98
		25	0.14±0.00	0.99	0.22±0.00	0.99

[1)] Values are mean±SD of triplicate measurements.

of storage. Their dynamic moduli increased with an increase in storage temperature from 5 to 25°C (Fig. 1), whereas there were not much differences between tan δ values of samples. Such increased dynamic moduli with increasing storage temperature can be attributed to the higher hydration properties and greater hydrogen bonding activity of gums in HPSP at higher storage temperatures. The differences between dynamic moduli values of 0- and 3-month storages in the HPSP-gum mixture systems also increased with an increase in storage temperature. The dynamic moduli of the HPSP-xathan gum mixture at 0-month storage were lower than those of the HPSP-guar gum mixture, indicating that there is more pronounced synergistic effect on viscoelastic properties by the addition of guar gum to HPSP samples. The increase in dynamic moduli with storage temperature is less pronounced at HPSP-xanthan gum mixtures in comparison to HPSP-guar gum mixtures. This indicates that changes in rheological properties of HPSP during storage at various temperatures can be decreased by the addition of xanthan gum rather than guar gum. In addition, there were only slight differences between dynamic moduli values of 0- and 3-month storage at 5 to 15°C, which suggests that the lower storage temperatures had a little effect on the viscoelastic properties of HPSP mixed with guar gum and xanthan gum (Table 1 and Fig. 1). From these observations, it was determined that the vicoelastic properties of HPSP samples mixed with guar gum and xanthan gum could be increased during storage and did not seem to be influenced by the lower storage temperatures (5 and 15°C).

Log (G', G") versus log ω data were subjected to linear regression, and the slope values and the coefficient of determination (R^2) were obtained, as shown in Table 2. The slopes of G' (0.16-0.18) of HPSP-guar gum mixtures at 3-month storage were much higher than that (0.10) at 0-month storage (Table 2), indicating that the elastic properties of the HPSP-guar gum mixtures can be decreased after 3-month storage. It has also been known that there was a more pronounced effect of guar gum on the viscous properties of HPSP-guar gum (14) and rice starch-guar gum mixtures (15). The G' slopes of HPSP-xanthan gum mixtures at 3-month storage were lower than those of HPSP-guar gum mixtures, indicating that the elastic properties were more pronounced at HPSP-xanthan gum mixtures in comparison to HPSP-guar gum mixtures. Our previous study (12) showed that a more pronounced effect of xanthan gum on the elastic properties was also observed in the gum solution system when compared to other gums. For the HPSP-xanthan gum mixtures, there were not much difference between G' slopes at 0-month and 3-month storages, suggesting that xanthan gum increases the structural stability of HPSP during storage. From the above observations, it can be concluded that the addition of xanthan gum to HPSP has a pronounced effect of the structural stability in the HPSP-xanthan gum systems during storage, especially at lower temperatures (5 and 15°C).

Acknowledgments

This work was supported by Korea Research Foundation Grant funded by the Korean Goverment (MOEHRD) (KRF-2005-041-F00068).

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