The Reducing of Starch Retrogradation for Wide Strip Rice Noodle Production under Cold Storage

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Abstract

This research was aimed to reduce retrogradation of starch for strip rice noodle production under cold storage. The flours were added with the variations of sodium steroyl-2-lactylate (SSL) at 0 and 0.5 % combined with tea polysaccharide (TPS), xanthan gum (XG) or carboxymethyl cellulose (CMC) at 0, 2.5, 5 and 7.5%. The mixture of flour slurry was determined for the gelatinization and retrogradation by Differential Scanning Calorimeter (DSC), and texture parameters of the gels kept under chilling condition at 8+2°C for 0, 4, 7, 10 and 14 days were detected by Texture Profile Analysis (TPA). The results showed that flour including SSL 0.5% combined with TPS 5% provided the lowest retrogradation ratio, hardness of the gel was not change whereas springiness and chewiness decreased but cohesiveness increased during 14 days of storage time

Keywords : retrogradation, flour, noodle, strip rice noodle, storage

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Introduction

Wide strip rice noodle is short, thin and flat shape which one of the most popular traditional food produced from rice in Thailand. Texture of fresh wide strip rice noodle is soft and slightly sticky. The shelf life of the rice noodle is too short. Therefore the manufacturers solve that problem by kept its in refrigerator or under cold storage. But the consumers unaccepted the texture of that rice noodle because that becomes to be hard, relentless and brittle.

The wide strip rice noodle is a one of rice flour products. Rice flour products are known to become hard, andthey decline in texture and taste over time, especially keep under cold storage. This phenomenon is generally called retrogradation. Retrogradation is a process in which themolecules of gelatinized starch reassociate to form crystallites uponcooling, which imply fully reversible recrystallization in the case ofamylopectin and partially irreversible recrystallization in the caseof amylose (Björk, 1996). Therefore, the technology of preparingrice flour products with extended shelf life or using rice floureffectively requires efficient retarding of starch retrogradation(Wu et al., 2010).

One method to increase shelf life of storage-based gels at low temperature is storage of those gels with high moisture content. However, this could enhance retrogradation in the products leading to changes in quality, especially in the texture of the stored product. Emulsifiers and surfactants have been used in the food industry as crumb softening agents and amylose complexing agents in starch based food (Moorthy, 1985) by which the surfactant retards the firming process of crumbs is based on their ability to form complexes with amylose to retardin the staling rate (Conde-petit and Escher, 1991).Phatthalung et al. (2008) studied the effect of surfactants on the retrogradation rate during extending the shelf life of noodles by refrigeration. The results showed that the addition of 0.5% SSL (sodium steroyl-2-lactate), 0.2% GMS (glycerol monostearate) and 0.5% MG (mogoglyceride) minimized the breaking force and maximized the breaking distance of noodles and lowered the enthalpy of retrogradation. SSL lowered the enthalpy of regradation more than GMS and MG. That implied to the maximum improvement of noodle quality was obtained with the addition of SSL 0.5% followed by GMS 0.2% and MG 0.5%

In addition, hydrocolloids have been widely used in food formulation to improve or to maintain the overall quality during distribution and storage by modifying the rheological and textural properties of foods (Pongsawatmanit et al., 2013). Zhou et al. (2008) researched the effect of polysaccharides on gelatinization and retrogradation of wheat starchafter 20 days of storage at 4°C and reported that the retrogradation rate of the control was eight times higher than samples containing 5% TPS (tea polysaccharide) and two times higher than samples containing 5% CMC (carboxymethyl cellulose). The overall results demonstrated that the inhibitory effect of TPS was greater than that of CMC under the same conditions.Whereas, Pongsawatmanit et al. (2013) suggested that 0.5% xanthan gum could retard the retrogradation of tapioca starch gels for longer storage time at 5°C.

In this study, SSL were combined with polysaccharide (PS) to investigate retrogradation ratio and gel texture during storage under cold storage, using thermal analysis and TPA (texture profile analysis). The objective of the present study was to compare the properties of SSL and polysaccharides to reduce retrogradationof rice starch for wide strip rice noodle production under cold storage.

Materials and Methods

Materials

Rice flour (Signtotong, Kamphaengphet rice was grind and sifted through a sieve of 80 mesh), SSL, TPS, XG and CMCwere used in experiments.

Preparation of gels

Gel preparation from powders of rice flour added with the variations of sodium steroyl-2-lactylate (SSL) at 0 and 0.5% w/w combined with tea polysaccharide (TPS), xanthan gum (XG)or carboxymethyl cellulose (CMC) at0, 2.5, 5 and7.5% w/wwas modified from the method ofPongsawatmanit et al. (2013). The concentrations of rice flour mixture in distilled water were 25% w/w in a beaker to achieve a total weight of 200 g and stirred with a magnetic stirrer to ensure complete hydration of the flour mixtures. The dispersion was heated in an oil bath to 95°C and heated further by holding at 95-98°C for 30 min with continuous stirring by a magnetic stirrer. Boiled hot distilled water was added into the hot mixtures for adjusting the total polysaccharide concentration to 25% w/w then mixture immediately. Hot mixtures were poured into cylindrical Teflon molds with 20 mm diameter (20 mm height for TPA), packed in plastic bag before placing in a refrigerator at 8±2°C. Samples were taken after 0, 4, 7, 10 and 14 days for TPA test.

Determination of retrogradation of rice flour and SSL combined with polysaccharides

The thermal properties of rice flour added with the variations of sodium steroyl-2-lactylate (SSL) at 0 and 0.5% w/w combined with tea polysaccharide (TPS), xanthan gum (XG)or carboxymethyl cellulose (CMC) at0, 2.5, 5 and7.5% w/w were measured using a differential scanning colorimeter (Mettler-Toledo Ltd., USA).Rice flour mixture was added into the dispersions with continuedstirring for a further 30 min. About 15 mg of the dispersions wereweighed directly into a 40-lL aluminum DSC pan and the pan washermetically sealed. Gelatinization behaviors of rice flour mixtureswere investigated by heating the pans from 25°C to 110°C at aheating rate of 5°C/min. Another empty DSC pan was used as a reference.The onset temperature (T_o), peak temperature (T_p) and conclusiontemperature (T_c) were determined based on DSCthermograms. Gelatinizationenthalpy (ΔH_1) expressed as J/g dry starch was evaluatedbased on the area of the main endothermic peak. After thefirst-run heating, the gelatinized rice flour mixture pastes were cooleddown to 25°C with a cooling rate of 10°C/min and kept at 8±2°C for0, 4, 7, 10 and 14 days. The stored samples were then reheatedagain to study the effect of SSL and polysaccharides on the retrogradation of rice flour usingthe parameter of the retrogradation ratio determined by dividingthe enthalpy of disintegration of the ordered structure (ΔH_2) inthe second-run heating by the gelatinization enthalpy in thefirst-run heating (ΔH_1). Each sample pan was weighed beforeand after measurement to ensure that no weight was lost during the measurement. Three independent sets of samples were preparedand the average value was reported (Pongsawatmanit et al., 2013).

Texture profile analysis (TPA)

Textureprofile analysis (TPA) of the gels was determined by the method modified from Hormdok and Noomhorm (2007). The gel sample was compressed by acylinder probe (35.0mm diameter) until the deformationreached 75% at a speed of 1.0 mm/s. The pause betweenthe first and second compressions were 0.5 s. From the force–time curve of the texture profile, textural parameters including hardness, adhesiveness and chewiness were obtained. The measurements were repeated 10 times for each sample.

Statistical analysis

The means and standard deviations were determined for all retrogradation ratio and texture properties. The significant difference of mean values was assessed with CRD and T-Test of variance (ANOVA) followed by Duncan's test using SPSS software at a significance level of ($P < 0.05$).

Results and Discussion

The most of retrogradation of the rice flour mixtures increased as storage time except the flour mixed with SSL 0.5% combined with TPS decreased and that flour mixtures combined with CMC 5.0% was not change. Samples blended with TPS exhibited the lowest retrogradation ratio at all storage time. Synergy between SSL and TPS reduced the retrogradation ratio but induced XG and CMC for increasing that ratio during storage (Table 1)

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Textures of rice flour gels in the parameters of hardness, springiness, chewiness and cohesiveness during storage exhibited in Table 2-5. The gel without SSL and polysaccharides addition was higher hardness value but lower springiness, chewiness and cohesiveness values as increasing storage time. SSL combined withTPS maintained hardness values of the gels whereas the other polysaccharides increased those values of the gels during storage.TPS decreased springiness but XG and CMC increased springiness value of the gels. The springiness values of all sample gels were decreased as increasing storage time. SSL and polysaccharide decreased chewiness and cohesiveness values of the gels. The most of the gels were lower chewinessvalueas increasing the storage time; whereas the gels mixed with SSL 0.5% combined with CMC 5.0% maintained chewiness values during storage.The cohesiveness of the gels added SSL 0.5% and TPS 5.0% increased at 14 days storage when compared with o day storage.

The results implied that the combination of SSL 0.5% and TPS 5.0% suitable to reduce retrogradation of rice flour. This support the previous observation that SSL 0.5% retarded retrogradation of Thai noodles kept at 9°C by SSL and amylose complex formation (Phatthalung et al., 2008). Moreover, this results also agreed with the report of Zhou et al. (2008) which found that the wheat starch containing TPS 5.0% revealed the retrogradation rate were lower than control and the sample containing CMC 5.0% therefore the inhibitory effect of TPS was greater than that of CMC under the same conditions. It might be due to differences in the behavior of starch mixtures containing TPS or CMC can be linked to the recrystallization or the retrogradation behavior of gelatinized starch. Those hydrocolloids acted as a water binder in aqueous starch mixtures, effectively depriving the amylose or amylopectin of usable for crystallization and preventing starch retrogradation (Lee et al., 2002). It might cause to the gel of the rice flour blended with SSL 0.5% and TPS 5.0%maintained hardness values, reduce springiness and chewiness but increase cohesiveness values of the gel during storage at 8±2°C.

Table 1 Retrogradation ratio ($\Delta H_2/\Delta H_1$) for rice flour mixtures on reheating

SSL (%)/PS (%)	Storage time (days)			
	4	7	10	14
0/0	1.211±0.197^{d,D}	1.3543±0.070^{c,C}	1.6121±0.537^{g,B}	1.9748±0.289^{f,A}
0/TPS 2.5	2.4662±0.459^{a,D}	3.2558±0.615^{a,C}	3.5532±0.240^{e,,B}	4.2870±0.106^{d,A}
0/TPS 5.0	2.2443±0.707^{ab,D}	2.6052±0.989^{b,C}	2.9633±0.233^{f,B}	3.2396±0.077^{e,A}
0/TPS 7.5	1.9445±0.056^{b,B}	2.4171±0.028^{b,AB}	2.5898±0.304^{f,A}	2.7898±0.176e,^{A}
0/XG 2.5	0.7917±0.494^{f,B}	1.2168±0.141^{c,AB}	1.2467±0.424^{g,A}	1.3114±0.509^{f,A}
0/XG 5.0	1.2165±0.417^{d,C}	1.6001±0.968^{bc,B}	1.6991±0.700^{g,AB}	1.9628±0.000^{f,A}
0/XG 7.5	1.6704±0.170^{c,BC}	1.8132±0.056^{bc,BC}	2.4476±0.664^{f,AB}	2.9763±1.173^{e,A}
0/CMC 2.5	1.3166±0.459^{cd,AB}	1.5141±0.247^{c,A}	1.3100±0.664^{g,AB}	1.7049±0.141^{f,A}
0/CMC 5.0	1.1599±0.562^{d,NS}	1.3252±0.408^{c,NS}	1.4208±0.007^{g,NS}	1.5253±0.007^{f,NS}
0/CMC 7.5	1.4938±0.070^{cd,C}	1.7160±0.452^{bc,C}	2.8913±0.947^{f,B}	3.7864±0.205^{e,A}
0.5/0	1.1739±3.309^{d,D}	1.7826±2.071^{bc,B}	4.7826±0.007^{d,A}	1.3652±0.014^{f,C}
0.5/TPS 2.5	1.0845±0.035^{e,C}	2.0845±0.000^{b,A}	0.7042±0.000^{h,D}	1.2816±0.021$^{f\ B}$,
0.5/TPS 5.0	1.0000±0.021^{e,A}	0.8256 ±0.021^{d,B}	0.6880±0.021^{h,C}	0.4128±0.035^{g,C}
0.5/TPS 7.5	1.2096±0.021^{d,BC}	1.8709±0.000^{bc,A}	1.3870±0.014^{g,B}	2.1612±0.042^{e,A}
0.5/XG 2.5	1.2598±0.537^{d,B}	0.4173±1.272^{d,C}	1.3386±0.056^{g,AB}	2.4961±0.021^{e,A}
0.5/XG 5.0	1.0833±0.774^{e,C}	3.4167±1.788^{a,C}	6.6667±0.091^{a,B}	7.7250±0.021^{b,A}
0.5/XG 7.5	0.9195±0.065^{e,D}	1.1839±1.930^{c,C}	5.3448±0.035^{b,B}	10.6322±0.007^{a,A}
0.5/CMC 2.5	1.0518±0.820^{e,C}	1.8818±1.513^{bc,B}	2.8182±0.014^{f,A}	2.382±0.035^{e,A}
0.5/CMC 5.0	1.0526±2.008^{e,C}	1.0526±9.015^{c,C}	2.4812±0.028^{f,B}	4.0602±0.028^{d,A}
0.5/CMC 7.5	0.9402±0.806$^{e\ C}$,	0.9658±0.021^{d,C}	3.2479±0.014^{e,B}	5.0427±0.014^{c,A}

Means ± standard deviation values of (n = 3) within the same column followed by different superscripts ($^{a-h}$) for different rice flour mixtures ; within the same row by different superscript letters ($^{A-D}$) are significantly different ($p < 0.05$) and by NS are not significantly different ($p \geq 0.05$) for different storage time by Duncan's multiple range test.

Table 2 Hardness (N) of riceflour gels during storage at 8±2°C

SSL (%)/PS (%)	Storage time (day)				
	0	4	7	10	14
0/0	12.779±0.731^{b,C}	13.327±0.767^{ns,AB}	14.124±1.645^{a,A}	13.204±1.953^{ns,B}	14.750±1.036^{a,AB}
0/TPS 2.5	13.763±1.523^{a,NS}	13.412±0.914^{ns,NS}	12.995±1.045abc,^{NS}	13.834±1.045^{ns,NS}	14.146±2.568^{ab,NS}
0/TPS 5.0	12.327±1.379^{ab,NS}	12.461±2.359^{ns,NS}	12.991±1.143bc,^{NS}	14.368±1.490^{ns,NS}	14.926±1.099^{a,NS}
0/TPS 7.5	12.497±0.243^{ab,NS}	13.627±1.094^{ns,NS}	14.509±1.179^{abc,NS}	14.468±2.377^{ns,NS}	14.862±2.329^{bc,NS}
0/XG 2.5	11.571±0.421^{b,NS}	12.497±1.498^{ns,NS}	12.569±1.564^{bc,NS}	13.489±0.427^{ns,NS}	13.553±1.177^{bc,NS}
0/XG 5.0	12.292±0.427^{ab,C}	12.954±0.703^{ns,BC}	13.271±0.531^{abc,BC}	13.904±0.981^{ns,B}	15.002±0.693^{abc,A}
0/XG 7.5	12.609±0.304^{ab,NS}	12.919±1.158^{ns,NS}	13.346±1.235^{abc,NS}	14.118±1.425^{ns,NS}	14.222±0.958^{abc,NS}
0/CMC 2.5	12.490±0.373^{ab,C}	13.449±0.306^{ns,,B}	13.414±0.547^{abc,B}	14.246±0.135^{ns,A}	14.651±0.399^{abc,A}
0/CMC 5.0	11.476±0.322^{ab,C}	12.468±0.366^{ns,BC}	13.623±0.000^{c,AB}	13.764±0.161^{ns,A}	14.092±0.746^{abc,A}
0/CMC 7.5	12.325±1.112^{ab,B}	13.594±0.793^{ns,AB}	13.060±0.975$^{bc\ A}$,	13.799±0.061^{ns,A}	13.799±0.763^{abc,A}
0.5/0	12.358±0.457^{ab,C}	12.960±0.531^{ns,BC}	14.128±0.484^{abc,AB}	13.904±0.792^{ns,AB}	14.749±0.265^{abc,A}
0.5/TPS2.5	13.384±2.514^{ab,NS}	12.678±0.915^{ns,NS}	13.095±0.211^{bc,NS}	13.166±0.244^{ns,NS}	14.646±0.245^{abc,NS}
0.5/TPS 5.0	12.517±2.122^{ab,NS}	13.171±0.121^{ns,NS}	14.083±0.881^{bc,NS}	14.083±0.881^{ns,NS}	13.236±0.322^{bc,NS}
0.5/TPS7.5	12.748±0.371^{ab,B}	13.418±0.106^{ns,AB}	14.081±1.780^{abc,AB}	14.996±0.211^{ns,A}	14.987±0.203^{c,A}
0.5/XG 2.5	12.398±0.703^{ab,NS}	13.171±0.531^{ns,NS}	13.236±1.057^{abc,NS}	13.236±1.418^{ns,NS}	14.010±1.878^{abc,NS}
0.5/XG 5.0	12.221±0.687^{ab,NS}	12.854±1.084^{ns,NS}	13.062±1.458^{bc,NS}	13.975±0.487^{ns,NS}	13.797±0.429^{abc,NS}
0.5/XG 7.5	11.693±0.581^{b,B}	13.064±0.958^{ns,AB}	12.640±1.171^{bc,AB}	13.482±1.567^{ns,AB}	14.763±0.851^{abc,A}
0.5/CMC2.5	13.242±0.581^{ab,B}	13.677±0.320^{ns,AB}	13.489±0.122^{abc,AB}	13.940±0.484^{ns,AB}	14.186±0.581^{abc,A}
0.5/CMC 5.0	13.102±0.048^{ab,B}	13.030±0.645^{ns,B}	13.025±0.265^{abc,B}	13.025±0.265^{ns,A}	14.365±0.180^{abc,A}
0.5/CMC7.5	11.542±0.440^{b,B}	12.327±0.670^{ns,AB}	14.159±0.460^{ab,AB}	14.159±0.460^{ns,A}	14.316±2.378^{abc,A}

Means ± standard deviation values of (n = 3) within the same column followed by different superscripts ($^{a-c}$) and by ns are not significantly different ($p \geq 0.05$) for different rice flour mixtures; within the same row by different superscript letters ($^{A-C}$) are significantly different ($p < 0.05$) and by NS are not significantly different ($p \geq 0.05$) for different storage time by Duncan's multiple range test.

Table 3 Springiness(mm) of rice flour gels during storage at 8±2°C

SSL (%)/PS (%)	Storage time (day)				
	0	4	7	10	14
0/0	45.130±2.028^{fgh,A}	38.401±0.312^{hi,B}	33.521±2.237^{f,C}	31.666±2.117^{f,C}	27.487±0.248^{efg,D}
0/TPS 2.5	46.318±1.400^{fg,A}	35.166±1.848^{jk,B}	33.499±0.935^{f,CV}	31.394±0.961^{f,C}	23.917±1.675^{h,D}
0/TPS 5.0	46.405±2.914^{fg,A}	41.386±1.117^{efgh,AB}	37.754±1.236^{cd,AB}	33.849±1.708^{cde,B}	29.257±1.001^{def,C}
0/TPS 7.5	45.079±2.113^{fgh,A}	39.719±1.760^{ghi,B}	37.259±0.667^{d,B}	34.302±1.123^{cd,C}	31.695±1.041^{bcd,C}
0/XG 2.5	48.323±1.988^{efg,A}	42.104±1.634^{efg,B}	37.516±0.664^{cd,C}	34.486±0.631^{cd,CD}	32.840±3.160^{abc,D}
0/XG 5.0	49.439±4.835^{efg,A}	43.816±1.294^{def,B}	43.049±1.518^{a,B}	37.672±0.986^{a,C}	34.407±2.040^{ab,C}
0/XG 7.5	53.164±2.737^{de,A}	48.170±1.910^{bc,B}	43.260±2.057^{a,C}	38.878±0.337^{a,CD}	35.466±3.933^{a,D}
0/CMC 2.5	67.368±2.619^{a,A}	52.846±3.374^{a,B}	44.125±1.354^{a,C}	32.720±0.864^{def,D}	29.501±0.785^{de,D}
0/CMC5.0	59.680±1.136^{bc,A}	48.751±2.957^{b,B}	43.531±1.799^{a,C}	37.764±1.122^{a,D}	34.618±1.594^{ab,D}
0/CMC 7.5	61.714±1.299^{b,A}	45.517±1.929^{cd,B}	40.492±0.551^{b,C}	37.030±0.852^{ab,D}	34.820±0.715^{a,E}
0.5/0	44.899±6.899^{fgh,A}	38.559±1.178^{hi,B}	33.715±0.607^{ef,BC}	31.550±1.398^{f,C}	28.961±0.672^{def,C}
0.5/TPS2.5	34.558±1.404^{i,A}	31.473±1.033^{l,B}	28.779±1.762^{g,C}	25.954±1.015^{h,D}	23.513±0.628^{h,E}
0.5/TPS 5.0	36.663±1.379^{ij,A}	33.030±1.742^{ki,B}	30.439±1.161^{g,C}	27.289±1.048^{gh,D}	24.609±1.209^{gh,E}
0.5/TPS7.5	43.805±0.300^{gh,A}	38.854±0.280^{ghi,B}	37.801±0.757^{cd,B}	34.759±0.637^{c,C}	30.358±2.005^{cde,D}
0.5/XG 2.5	49.722±5.152^{ef,A}	39.358±2.080^{ghi,B}	35.493±2.059^{def,B}	27.790±1.388^{gh,C}	24.625±1.647^{gh,C}
0.5/XG 5.0	40.184±0.605^{hi,A}	38.005±1.053^{ij,A}	35.204±2.184^{def,B}	32.132±0.221^{ef,C}	29.687±1.597^{de,D}
0.5/XG 7.5	46.328±0.503^{fg,A}	42.174±0.790^{efg,B}	39.970±0.937^{bc,C}	35.607±0.381^{bc,D}	33.045±0.263^{abc,E}
0.5/CMC2.5	46.866±3.859^{fg,A}	40.653±2.144^{fgh,B}	34.053±1.119^{ef,C}	29.101±1.015^{g,D}	24.497±1.562^{gh,E}
0.5/CMC 5.0	45.865±1.921^{fg,A}	41.809±0.733^{efgh,B}	36.407±1.014^{de,C}	31.125±0.967^{f,D}	27.954±1.063^{ef,E}
0.5/CMC7.5	55.046±4.154^{cd,A}	44.109±3.016^{de,B}	35.117±2.258^{def,C}	31.409±0.356^{f,C}	26.327±1.146^{fgh,D}

Means ± standard deviation values of (n = 3) within the same column followed by different superscripts ($^{a-j}$) for different rice flour mixtures; within the same row by different superscript letters ($^{A-E}$) are significantly different(p < 0.05) for different storage time by Duncan's multiple range test.

Table 4 Chewiness (N*mm) of rice flour gels during storage at 8±2°C

SSL (%)/PS (%)	Storage time (day)				
	0	4	7	10	14
0/0	2.084±0.490^{a,A}	0.632±0.111^{cdefg,B}	0.534±0.017^{bcd,B}	0.509±0.040^{abcde,B}	0.226±0.006^{fg,B}
0/TPS 2.5	1.136±0.083^{bcd,A}	0.680±0.116^{bcdef,BC}	0.837±0.106^{a,B}	0.562±0.041^{abcd,C}	0.179±0.061^{g,D}
0/TPS 5.0	1.355±0.113^{b,A}	0.805±0.088^{ab,B}	0.659±0.034^{bc,BC}	0.609±0.041^{ab,C}	0.391±1.06^{abcde,D}
0/TPS 7.5	1.185±0.138^{bc,A}	0.090±0.102^{a,B}	0.695±0.041^{ab,C}	0.591±0.028^{abc,C}	0.289±0.068^{ef,D}
0/XG 2.5	0.794±0.048^{efgh,A}	0.700±0.036^{bcdef,AB}	0.621±0.082^{bcd,BC}	0.504±0.012^{abcde,C}	0.344±0.097^{cde,D}
0/XG 5.0	0.954±0.183^{cdef,A}	0.766±0.078^{abcd,AB}	0.668±0.130^{b,BC}	0.512±0.207^{abcde,BC}	0.435±0.124^{abcd,C}
0/XG 7.5	0.982±0.234^{cde,A}	0.765±0.059^{abcd,AB}	0.642±0.125^{bcd,BC}	0.544±0.078^{abcd,BC}	0.477±0.019^{a,C}
0/CMC 2.5	0.582±0.047^{h,A}	0.465±0.054^{hi,B}	0.475±0.059^{c,B}	0.471±0.024^{bcde,B}	0.341±0.078^{cde,C}
0/CMC5	0.922±0.069^{cdefg,A}	0.690±0.131^{bcdef,B}	0.565±0.016^{bcd,BC}	0.444±0.023^{cde,CD}	0.391±0.073^{abcde,D}
0/CMC 7.5	0.585±0.077^{h,A}	0.505±0.017^{ghi,AB}	0.471±0.085^{c,AB}	0.440±0.036^{de,B}	0.432±0.080^{abcd,B}
0.5/0	0.852±0.068^{defgh,A}	0.705±0.058^{bcdef,B}	0.597±0.015^{bcd,C}	0.533±0.041^{abcde,CD}	0.464±0.039^{ab,D}
0.5/TPS2.5	0.906±0.033^{cdefg,A}	0.779±0.105^{abc,A}	0.584±0.057^{bcd,B}	0.529±0.181^{abcde,BC}	0.386±0.048^{abcde,D}
0.5/TPS 5.0	0.759±0.198^{efgh,A}	0.605±0.037^{defgh,AB}	0.644±0.013^{bcd,AB}	0.606±0.034^{ab,AB}	0.505±0.049^{a,B}
0.5/TPS7.5	0.907±0.060^{cdefg,A}	0.747±0.040^{abcde,B}	0.631±0.120^{bcd,B}	0.457±0.034^{cde,C}	0.356±0.046^{bcde,C}
0.5/XG 2.5	0.663±0.096^{fgh,A}	0.583±0.109^{egfh,A}	0.529±0.079^{bcd,A}	0.389±0.032^{e,B}	0.325±0.013^{def,B}
0.5/XG 5.0	0.881±0.121^{cdefgh,A}	0.766±0.113^{abcd,AB}	0.645±0.036^{bcd,BC}	0.573±0.059^{abcd,CD}	0.480±0.026^{a,D}
0.5/XG 7.5	0.793±0.050^{efgh,A}	0.659±0.122^{bcdefg,B}	0.594±0.041^{bcd,BC}	0.531±0.064^{abcde,C}	0.476±0.021^{a,C}
0.5/CMC2.5	0.850±0.069^{defgh,A}	0.391±0.068^{i,C}	0.621±0.052^{bcd,B}	0.651±0.036^{a,B}	0.460±0.033^{abc,C}
0.5/CMC 5.0	0.615±0.143^{gh,NS}	0.549±0.109^{fgh,NS}	0.484±0.251^{cd,NS}	0.476±0.074^{bcde,NS}	0.429±0.033$^{abcd.NS}$
0.5/CMC7.5	0.755±0.178^{efgh,A}	0.574±0.068^{fgh,B}	0.523±0.018^{bcd,B}	0.430±0.020^{de,BC}	0.343±0.022^{cde,C}

Means ± standard deviation values of (n = 3) within the same column followed by different superscripts ($^{a-i}$) for different rice flour mixtures; within the same row by different superscript letters ($^{A-D}$) are significantly different($p < 0.05$) and by NS are not significantly different ($p \geq 0.05$) for different storage time by Duncan's multiple range test.

Table 5 Cohesiveness (N/m) of rice flour gels during storage at 8±2°C

SSL (%)/PS (%)	Storage time (day)				
	0	4	7	10	14
0/0	0.1463±0.0110^{c,A}	0.1433±0.0005^{g,A}	0.1136±0.0020^{hg,D}	0.1293±0.0011^{ab,b}	0.1210±0.0036^{f,C}
0/TPS 2.5	0.1410±0.0026^{cd,D}	0.1906±0.0005^{b,A}	0.1720±0.0020^{a,B}	0.1333±0.0032^{a,E}	0.1456±0.0030^{b,C}
0/TPS 5	0.1820±0.0175^{a,B}	0.1630±0.0000^{e,C}	0.1146±0.0037^{fg,D}	0.1156±0.0020^{hi,D}	0.2276±0.0056^{a,A}
0/TPS 7.5	0.1450±0.0034^{cd,B}	0.1706±0.0011^{d,A}	0.1160±0.0030^{fg,C}	0.1170±0.0062^{gji,C}	0.1413±0.0047^{bc,B}
0/XG 2.5	0.1316±0.0075^{ef,A}	0.1146±0.0037^{gi,B}	0.1153±0.0035^{fg,B}	0.1243±0.0032^{def,A}	0.1270±0.0000^{e,A}
0/XG 5	0.1320±0.0026^{ef,B}	0.1533±0.0089^{f,A}	0.1320±0.0000^{c,B}	0.1123±0.0005^{efg,C}	0.1356±0.0025^{cd,B}
0/XG 7.5	0.1776±0.0050^{ab,A}	0.1156±0.0035^{hi,D}	0.1213±0.0015^{e,C}	0.1223±0.0025^{efg,BC}	0.1273±0.0011^{e,B}
0/CMC 2.5	0.1136±0.0015^{hi,B}	0.1093±0.0011^{i,C}	0.1063±0.0005^{h,D}	0.1050±0.0010^{f,D}	0.1240±0.0017^{ef,A}
0/CMC5	0.1266±0.001^{fg,B}	0.1013±0.0005^{j,D}	0.1153±0.0015^{fg,C}	0.1233±0.0040^{ef,B}	0.1443±0.0015^{b,A}
0/CMC 7.5	0.1236±0.0005^{fg,B}	0.1096±0.0005$^{i.D}$	0.1150±0.0000^{fg,C}	0.1193±0.0015^{fgh,B}	0.1026±0.0025^{h,E}
0.5/0	0.1306±0.0011^{ef,B}	0.1710±0.0017^{d,A}	0.1250±0.0010^{d,V}	0.1213±0.0023^{fgh,D}	0.1326±0.0028^{d,B}
0.5/TPS2.5	0.1736±0.0025^{b,B}	0.2110±0.0010^{a,A}	0.1320±0.0035^{c,C}	0.1196±0.0066^{efg,D}	0.1330±0.0010^{d,C}
0.5/TPS 5	0.1250±0.002^{fg,D}	0.1810±0.0000^{c,A}	0.1336±0.0023^{c,B}	0.1296±0.0005^{abc,C}	0.1326±0.0011^{d,B}
0.5/TPS7.5	0.1360±0.0017^{de,B}	0.1823±0.0120^{c,A}	0.1316±0.1120^{c,B}	0.1260±0.0026^{bcd,B}	0.1150±0.0026^{g,C}
0.5/XG 2.5	0.1210±0.0010^{gh,B}	0.1440±0.0020^{g,A}	0.1130±0.0017^{g,C}	0.1126±0.0025^{efg,C}	0.1156±0.0030^{g,C}
0.5/XG 5	0.1313±0.0032^{ef,B}	0.1430±0.0010^{g,A}	0.1326±0.0025^{c,B}	0.1306±0.0005^{ab,B}	0.1156±0.0005^{g,C}
0.5/XG 7.5	0.1300±0.0020^{ef,C}	0.1436±0.0005^{g,A}	0.1420±0.0020^{b,A}	0.1246±0.0035^{def,D}	0.1346±0.0025^{d,B}
0.5/CMC2.5	0.1146±0.0005^{hi,BC}	0.1160±0.0017^{hi,B}	0.1173±0.0005^{f,B}	0.1130±0.0010^{i,C}	0.1273±0.0023^{e,A}
0.5/CMC 5	0.1110±0.0010^{j,C}	0.1533±0.0020^{f,A}	0.1226±0.001de^{,B}	0.1140±0.0026^{i,C}	0.1023±0.0011^{h,D}
0.5/CMC7.5	0.1196±0.0005^{gh,B}	0.1176±0.0005^{h,B}	0.1350±0.0010^{c,A}	0.1023±0.0011^{j,D}	0.1143±0.0023^{g,C}

Means ± standard deviation values of (n = 3) within the same column followed by different superscripts ($^{a\text{-}j}$) for different rice flour mixtures; within the same row by different superscript letters ($^{A\text{-}E}$) are significantly different($p < 0.05$) for different storage time by Duncan's multiple range test.

Conclusions

It could be speculated through combining these results with those obtained from DSC and TPA stated above that the SSL and polysaccharides could reduce starch retrogradation for strip rice noodle production under cold storage. The result showed that maximum reducing retrogradation of rice flour was obtained with the addition of SSL 0.5% combined with TPS 5.0%.

Acknowledgement

This research work was supported by a grant from the Research and Researcher for Industry (RRI) (Grant No. MSD57I0142).

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