Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Annals of Biological Research, 2011, 2 (1) :181-186
(http://scholarsresearchlibrary.com/archive.html)

Scholars Research Library

ISSN 0976-1233
CODEN (USA): ABRNBW

Effects of sodium chloride, soy protein isolate and secondary gums on Konjac gel properties

Adisak Akesowan

Department of Food Science and Technology, School of Science and Technology, University of the Thai Chamber of Commerce, Bangkok, Thailand

---

ABSTRACT

The gel strength and textural properties (hardness and springiness) of 1% mixed gum gels (konjac flour:secondary gum = 3:2) prepared with and without added sodium chloride (NaCl) and soy protein isolate (SPI) were investigated. A factorial design with three factors including NaCl concentration (0, 0.5 and 1%), SPI concentration (0, 0.5 and 1%) and secondary gums (κ-carrageenan, xanthan and gellan gum) was applied. The change of mixed gels properties was mostly influenced by NaCl concentration. Increasing of NaCl resulted in the increase in gel strength and hardness of konjac/κ-carrageenan and konjac/gellan mixed gels but not in the konjac/xanthan mixed gel. The gel strength and hardness produced by konjac/gellan gels were higher than the others. There was no significant difference ($p > 0.05$) in springiness of konjac/xanthan mixed gel under added NaCl and SPI conditions, whereas decreased springiness values were observed for konjac/κ-carrageenan or gellan mixed gels with increasing of SPI addition.

Key words: Konjac flour, gel strength, textural property, secondary gum, soy protein isolate.

INTRODUCTION

Konjac flour or konjac gum, a neutral polysaccharide produced from the tuber of *Amorphophallus konjac* C. Koch, or *A. oncophyllus*, is mainly composed of a high molecular weight glucomannan in which D-mannose and D-glucose units in a ratio of 1.6:1 are connected by β–(1, 4)–glycosidic linkages [1]. It was classified to generally recognised as safe (GRAS) for use as thickening and gelling agents in foods. The gelling properties of konjac flour are affected by many factors such as molecular weight of konjac flour, acetyl group content and impurities [2]. Konjac gel can be formed, either by deacetylation in mild alkaline solution (i.e. calcium hydroxide) to get a hard and brittle gel or by interaction with secondary gums such as xanthan gum or κ-carrageenan to produce a more elastic gel, depending on types of food products and producers' purpose [3–4].

Gel property of konjac flour in processed and convenience foods and gelled systems is a major factor that affects the structure and perceived texture. Since foods are almost multicomponent, many interactions between different components occurred such as polysaccharide–polysaccharide interaction or polysaccharide–protein interaction. Consequently, the ability of konjac gel to exhibit rigidity and elasticity seems to be a function of type and concentration of secondary gums or polysaccharides, type and concentration of proteins, temperature and time of heating and ionic strength in the system [5–6]. In addition, the phase separation of mixed polymer systems and textural properties are dependent on processing temperature, polysaccharide and protein content and salt conditions [7]. These factors would affect konjac gel formation and properties that need to understand for better food formation in the production of low–fat food products or fortified foods.

So far, the finding of variables affecting the konjac gel is limited. Huang and Lin [5] revealed that gel strength and textural properties of konjac gels gelated in alkaline conditions were affected by hydrocolloids, pH and added salt. Nevertheless, the influence of variables on konjac gel properties gelated in another method by interacting with secondary gums is scarce. Therefore, this research was carried out to determine the effect of salt (sodium chloride), soy protein isolate (SPI) and secondary gums (κ-carrageenan, xanthan gum, gellan gum) on gel strength and texture (hardness and springiness) of konjac gels.

MATERIALS AND METHODS

Materials: Konjac flour (*A. konjac*) (Chengdu Newstar Chengming Bio-Tech Co., China), κ–carrageenan (MSC 5744, MSC Ltd., USA), xanthan gum (KELTROL©, CP Kelco, San Diego, CA, USA), gellan gum (KELOGEL®, CP Kelco, UK Ltd, UK) and Soy protein isolate (SPI) (PRO 500 A, Vichi Enterprise Co., Thailand) and an analytical grade sodium chloride (NaCl) were used.

Gel preparation: For all experiments, the concentration of total mixed gum (konjac flour and secondary gum = 3:2) was fixed at 1% (w/v) level. A mixed gum, NaCl and SPI were gradually added into distilled water and constantly stirred for 10 min using a magnetic stirrer. The mixture was heated at 90 ± 2°C for 30 min in a water bath with stirring (core temperature was reached at 85 ± 2°C). Then, the hot mixture was filled into gel cups (3 cm diameter x 2.1 cm height), cooled to room temperature (29 ± 2°C), and stored at refrigerated temperature (10 ± 2°C) for 24 h. Three batches for each gel strength and textural test were made. The results were the means of at least three reproducible runs.

Gel strength determination: Mixed gels prepared from different setting conditions were determined for gel strength by a texture analyser (Model LRX, Lloyd Instruments, Hampshire, UK). A 1000–N load cell and a test cell (10 mm diameter flat ended cylinder) were used to determine the gel strength. The crosshead speed and compression distance were 1 mms^{-1} and 10 mm, respectively. Five samples from each treatment were used for gel strength determination. Gel strength was calculated according to the following equation.

Gel strength = Maximum load (kgf) × Deflection at maximum load (cm)

Textural analysis: Gel samples were first removed from the cups; if gels were too soft to be removed, then the gel texture was not determined. Textural characteristics (hardness and springiness) of gels were determined using a texture analyser with a test cell (50 mm width x 50 mm length) at 2 mms^{-1}crosshead speed.

Experimantal design and data analysis: Three factors included: NaCl concentration (0, 0.5 and 1%), SPI concentration (0, 0.5 and 1%) and type of secondary gum (κ-carrageenan, xanthan gum and gellan gum) were studied. Data were statistically analysed for 3 x 3 x 3 factorial design using a GLM (general linear model). Analysis of variance (ANOVA) and the significance of mean differences were analysed by the statistical program SPSS for Window version 14.0. Duncan's new multiple range test was used for mean comparison for a treatment effect at the 5% significance level [8].

RESULTS AND DISCUSSION

The ANOVA results shown in Table 1 reveals that NaCl concentration, SPI concentration and type of secondary gum as well as all of their interactions significantly affected ($p < 0.05$) gel strength and hardness of konjac gels, except for the interaction between SPI concentration and type of secondary gum which showed no effect ($p > 0.05$) on hardness of the gels. For springiness, only a main effect of SPI concentration and the interaction between SPI concentration and type of secondary gum displayed significant effects ($p < 0.05$) on konjac gels. The largest effect on both gel strength and hardness was NaCl concentration, while the factor showing the largest effect on springiness was SPI concentration. However, its influence on gel strength and hardness depended on the other factors (NaCl and/or type of secondary gum). Because these three factors showed major and significant effects on gel strength and textural characteristics of konjac gels, result for these combinations were constructed as shown in Table 2-4.

Table 1. Three-way ANOVA of gel strength, hardness and springiness of konjac gels with different levels of NaCl, SPI and secondary gums

Source	Gel strength		Hardness		Springiness	
	F	P	F	P	F	P
Main effect:						
A : NaCl	50.205	0.000	767.849	0.000	1.586	0.211
B : SPI	10.082	0.000	24.829	0.000	3.350	0.040
C : Secondary gum	49.637	0.000	220.610	0.000	2.613	0.079
Interaction						
A × B	4.465	0.002	13.271	0.000	1.065	0.379
A × C	49.119	0.000	95.968	0.000	0.576	0.564
B × C	3.161	0.017	0.329	0.858	2.879	0.027
A × B × C	2.269	0.028	13.186	0.000	1.338	0.263

F – Statistics test to determine significance; P – probability value.

Gel strength

In an absence of added NaCl and SPI, it was observed that konjac flour mixed with secondary gums (κ-carrageenan, xanthan and gellan) can be formed heat-induced gels with different gel strength values depending on type of secondary gum used, as evidence in Table 2. The konjac/xanthan gel showed the significant highest ($p < 0.05$) gel strength whereas there was no significant difference ($p > 0.05$) in gel strength between konjac/gellan and konjac/κ-carrageenan gels on each setting condition. The konjac/xanthan mixed gel displayed more soft, elastic but tough texture in relation to other mixed gels which exhibited more brittle gel texture. This result implied that the gel characteristic would be related to gel strength where the elastic and tough konjac/xanthan mixed gel required more force to deform than the others, showing the highest gel strength.

Table 2. Gel strength of konjac gels with different levels of NaCl, SPI and secondary gums

NaCl (%)	SPI (%)	Mixed gum (konjac flour:secondary gum = 3:2)		
		Konjac/κ-carrageenan	Konjac/xanthan	Konjac/gellan
0	0	0.04 ± 0.01^{aA}	0.28 ± 0.01^{dB}	0.07 ± 0.02^{aA}
	0.5	0.07 ± 0.04^{bA}	0.24 ± 0.04^{cdB}	0.06 ± 0.01^{aA}
	1	0.08 ± 0.02^{bA}	0.24 ± 0.02^{cdB}	0.08 ± 0.01^{aA}
0.5	0	0.23 ± 0.01^{eA}	0.22 ± 0.03^{bcB}	0.25 ± 0.08^{cdA}
	0.5	0.21 ± 0.03^{deB}	0.16 ± 0.03^{aA}	0.19 ± 0.08^{bcB}
	1	0.15 ± 0.02^{cA}	0.21 ± 0.04^{abcB}	0.14 ± 0.03^{bA}
1	0	0.18 ± 0.03^{dA}	0.23 ± 0.05^{abcB}	0.22 ± 0.02^{cdA}
	0.5	0.19 ± 0.02^{dB}	0.17 ± 0.07^{abA}	0.19 ± 0.02^{bcB}
	1	0.19 ± 0.00^{dB}	0.18 ± 0.02^{abA}	0.19 ± 0.01^{bcB}

Gel strength expresses as maximum load (kgf) × deflection at maximum load (cm).
Different superscripts within the same column or row indicate that values differ significantly ($p < 0.05$).

When NaCl and SPI were added, there was an increased trend for gel strength of konjac/κ-carrageenan and konjac/gellan mixed gels with increasing of NaCl concentration while a decrease in gel strength of konjac/xanthan mixed gels was occurred as NaCl concentration was increased. Increasing NaCl levels enhanced the gel strength of konjac/κ-carrageenan or gellan gum mixed gels, possibly due to more ionic and hydrogen bonds formed between konjac molecules as a result of the ionic atmosphere, with an excess of ions of the charge opposite to that of anionic polysaccharides (κ-carrageenan and gellan gum), decrease the electrostatic free energy of the sysetm [9]. This result was in agreement with the work of Totosaus *et al.* [6], who showed that the gel strengths of gum-protein mixtures including gellan, κ-carrageenan, bovine serum albumin and egg white albumin were dependent upon the concentration and type of monovalent cation, resulting in strong gels with potassium ion than sodium ion.

As shown in Table 2, the addition of SPI significantly affected ($p < 0.05$) only the gel strength of konjac/κ-carrageenan mixed gel when gelated in no added NaCl condition; nevertheless, it showed no significant effect ($p > 0.05$) when NaCl was incorporated up to 1% level. The mixed gels between konjac flour and xanthan or gellan gum, with or without added NaCl, showed no significant differences ($p > 0.05$) in gel strengths at any levels of SPI addition. This was attributed to the interactions of konjac flour and xanthan or gellan produced heat-induced mixed gels with higher gel hardness than that with κ-carrageenan (Table 3), resulting in the rigid conformational structure or stronger network strength which hindered interactions between konjac flour and SPI [10].

Textural properties

Results for hardness of konjac/secondary gum mixed gels shown in Table 3 reveal that at 1% total gum (konjac flour and secondary gum = 3:2) prepared at 90 ± 2°C for 30 min and with or without SPI addition, the gel texture was too soft to be removed from the cups. This was propably due to the condition for gel preparation may not meet the optimum gelation of konjac/κ-carrageenan or gellan mixed gels and the interference of SPI by competing with konjac flour for water absorption in the mixture, which caused incomplete intermolecular association for junction zone formation between konjac flour and the gums. The increment of NaCl concentration appeared to increase hardness of mixed gels between konjac flour and κ-carrageenan or gellan gum; however, the gel hardness tended to decrease with increasing of SPI levels.

Table 3. Hardness of konjac gels with different levels of NaCl, SPI and secondary gums

NaCl (%)	SPI (%)	Mixed gum (konjac flour:secondary gum = 3:2)		
		Konjac/κ-carrageenan	Konjac/xanthan	Konjac/gellan
0	0	SG	3.94 ± 0.40^{e}	SG
	0.5	SG	4.01 ± 0.35^{e}	SG
	1	SG	3.69 ± 0.31^{e}	SG
0.5	0	1.43 ± 0.07^{cA}	2.48 ± 0.25^{dA}	1.91 ± 0.21^{abA}
	0.5	0.89 ± 0.10^{aA}	1.84 ± 0.09^{cC}	1.72 ± 0.18^{aB}
	1	1.00 ± 0.07^{abA}	1.53 ± 0.11^{bcB}	2.01 ± 0.18^{bcC}
1	0	1.38 ± 0.14^{cB}	1.20 ± 0.11^{abA}	2.95 ± 0.18^{eC}
	0.5	1.15 ± 0.03^{bB}	1.13 ± 0.19^{aA}	2.56 ± 0.11^{dC}
	1	1.00 ± 0.20^{abA}	1.25 ± 0.13^{abB}	2.20 ± 0.07^{cC}

Different superscripts within the same column or row indicate that values differ significantly ($p < 0.05$).
SG-soft gel that cannot be removed from the cups for textural determination.

The gelation of these two mixed gels may be possibly due to the effect of cation (Na^+) on binding the ordered κ-carrageenan conformed and helical conformation on counterion–carrageenan –konjac interactions. Whilst, sodium ions promoted the formation of double helices and the aggregation of these helices, where the junction zones in konjac/gellan gels become more binding to produce a harder structure with sodium ion [6]. It was also observed that konjac flour incorporated with gellan gum prepared at any levels of NaCl and SPI demonstrated higher gel hardness values than that with κ-carrageenan. The difference in gel hardness could be attributed to the difference in physical properties of the two gums [11]. When konjac flour were mixed with xanthan gum and gelled without added NaCl and SPI, the resulting gel hardness was not significantly different ($p > 0.05$) from that with the same condition but added SPI; however, the increase of NaCl and SPI decreased the hardness of the mixed gel [12].

Table 4 shows the gel springiness of mixed gels prepared with konjac flour and secondary gums at different conditions. The effect of both NaCl and SPI concentration on gel springiness were not consistent in all konjac/secondary gum mixed gels. However, in general, it was observed that the magnitude of the change of springiness was more pronounced by increasing SPI levels used. It was interesting to note that the addition of NaCl and SPI up to 1% level showed no significant effect ($p > 0.05$) on gel springiness of konjac/xanthan mixed gels.

Table 4. Springiness of konjac gels with different levels of NaCl, SPI and type of gum

NaCl (%)	SPI (%)	Mixed gum (konjac flour:secondary gum = 3:2)		
		Konjac/κ-carrageenan	Konjac/xanthan	Konjac/gellan
0	0	SG	4.87 ± 1.32^{a}	SG
	0.5	SG	4.64 ± 1.43^{a}	SG
	1	SG	5.08 ± 1.33^{a}	SG
0.5	0	4.08 ± 1.82^{bcA}	5.56 ± 1.15^{aB}	6.72 ± 0.62^{cB}
	0.5	3.67 ± 1.31^{aA}	5.78 ± 1.06^{aB}	4.63 ± 1.12^{bB}
	1	3.33 ± 1.15^{aA}	3.74 ± 0.94^{aB}	4.70 ± 1.25^{bB}
1	0	3.09 ± 0.97^{aA}	4.56 ± 1.42^{aB}	7.13 ± 0.75^{cB}
	0.5	2.36 ± 1.12^{aA}	3.46 ± 1.06^{aB}	2.53 ± 0.57^{aB}
	1	5.08 ± 1.01^{cB}	4.74 ± 0.85^{aA}	2.38 ± 0.78^{aA}

Different superscripts within the same column or row indicate that values differ significantly ($p < 0.05$).
SG-soft gel that cannot be removed from the cups for textural determination.

CONCLUSION

The gel strength and texture of konjac gels were affected by secondary gums and setting conditions with or without NaCl and/or SPI addition. The fact that NaCl addition did show more effects on konjac/κ-carrageenan and konjac/gellan mixed gels will produce different gel strength, hardness and springiness values depending on SPI addition. Under the same conditions, konjac/xanthan mixed gels showed no change in springiness with respect to that of other mixed gels. The influencing variables such as pH, gelling temperature and sucrose require further investigation.

Acknowledgements
The author wish to acknowledge the financial support from the University of the Thai Chamber of Commerce.

REFERENCES

[1] M.A. Williams, T.J. Foster, D.R. Martin, I.T. Norton, *Biomacromology*, **2000**, 1, 440.
[2] S. Takigami, In: G.O. Phillips and P.A. Williams (Eds.), Handbook of hydrocolloids, (Woodhead Publishing Limited and CRC Press LLC, Boca Raton, FL, **2000**) 413.
[3] R.J. Tye, *Food Technol*., **1991**, 45, 82.
[4] W.R. Thomas, In: A. Imeson (Ed.), Thickening and Gelling Agents for Food, 2nd ed., (Blackie Academic & Professional, London, **1997**) 169.
[5] H.Y. Huang, K.W. Lin, *Int. J. Food Sci. Technol.*, **2004**, 39, 1009.
[6] A. Totosaus, I. Guerrero, J.G. Montejano, *J. Texture Studies*, **2005**, 36, 78.
[7] M.C. Nunes, A. Raymundo, I. Sousa, *Food Hydrocolloids*, **2006**, 20, 106.
[8] W.G. Cochran, G.M. Cox, Experimental Design, 2 nd ed., (John Wiley and Sons, New York, **1992**) 613 pp.
[9] N.F. Stanley, In : P. Harris (Ed.), Food Gels (Elsevier Applied Science, London, **1990**), 79.
[10] X. Huang, C. Li, F. Yang, L. Xie, X. Xu, Y. Zhou, S. Pan, *Eur. Food Res. Technol.*, **2010**, 231, 751.
[11] F.O. Uruakpa, S.D. Armfield, *Int. J. Food Sci. Technol.*, **2005**, 40, 643.
[12] V.B. Tolstoguzov, *Food Hydrocolloids*, **1991**, 4, 429.