International Food Research Journal 23(4): 1474-1478 (2016)
Journal homepage: *http://www.ifrj.upm.edu.my*

Rheological, physical and sensory attributes of *Chao Kuay* jelly added with gelling agents

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Article history

Received: 18 May 2015
Received in revised form: 17 October 2015
Accepted: 8 December 2015

Keywords

Mesona procumbens Hemsl.
Chao Kuay jelly
Gelling agent
Textural property
Rheological behavior

Abstract

This work purposed to evaluate the qualities of *Chao Kuay* (*Mesona procurebens* Hemsl.) jelly combined with 3% and 6% (w/v) of different gelling agents including potato flour (commercial formula or control group), agar and carrageenan. Rheological behaviors, textural profiles, color parameters and sensory attributes of the products were determined. In this study, we found that types and levels of gelling agents had a significant effect on the qualities of *Chao Kuay* jelly. Color parameters indicated that jelly mixed with 3% potato flour was apparently darker than the other batches. The gel had a medium density of branched-structure, indicating by the viscoelastic behaviors. From textural properties and sensory scores, the results confirmed that 3% potato flour addition could be appropriate to ensure the good gel qualities for *Chao Kuay* jelly production.

Introduction

Chao Kuay or Hsian-Tsao (*Mesona procurebens* Hemsl.), a herbal plant belonging to Labiatae family, has been used as a jelly dessert by Thai and Chinese for centuries. Many health benefits of this herb including lowering blood pressure and diuretic effect were previously reported by Chen *et al.* (1996), Lai *et al.* (2000) and Widyaningsih *et al*. (2014). It is also useful in treating hot-shock, hypertension, diabetes and muscle pains (Lai *et al*., 2000; Kreungngern *et al*., 2013). Yen and Hung (2001) illustrated that phenolic compounds extracted from *Chao Kuay* significantly contributed to the antioxidant activity and free radical scavenging effects. In addition, Lai *et al*. (2001) demonstrated that *Chao Kuay* leaf gum is a potent polar antioxidant that interacts with a wide range of species directly responsible for oxidative damage.

Chao Kuay jelly is traditionally prepared through the addition of starch to the polysaccharide extract of the plant leaves. However, the gelling properties of polysaccharide gum from *Chao Kuay* leaves were found to be strongly influenced by various factors including extraction conditions, starch types and concentrations as well as parts of the plant (Lai *et al*., 2000). This gum can be extracted by using sodium bicarbonate or sodium carbonate and is reported to interact with starch synergistically, resulting in a noticeable increase in viscosity and the formation of a thermoreversible gel (Lai and Chao, 2000a, b; Lai *et al*., 2001). Yang and Huang (1990) reported that the gum can form resilient gels, which is possibly due to the high soluble non-nitrogen matter content in the leaves.

Texture is the most important characteristic of *Chao Kuay* jelly and the addition of several gelling agents including potato flour, agar, carrageenan and other hydrocolloids has been displayed to provide desirable texture, relating to the consumer acceptance. The most popular method for characterizing this property is oscillatory stress sweep measurement (Chaikham *et al*., 2012). Therefore, the objective of our research was to examine rheological behaviors, textural profiles, color parameters and sensory attributes of *Chao Kuay* jelly combined with 3% or 6% (w/v) of various gelling agents.

Materials and Methods

Chao Kuay jelly production

The dried *Chao Kuay* (*Mesona procumbens* Hemsl.) leaves were purchased from a local market in Kamphaeng Phet province, Thailand. In brief, 100 g of dried leaves were washed and continuously extracted in 3 L of boiling water (95±5ºC) containing

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0.25% (w/v) sodium carbonate for 6 h, before filtering through a filter cloth. Afterward, the heated filtrate was mixed with 3% and 6% (w/v) of gelling agents, such as potato flour (commercial formula or control group), agar and carrageenan, and immediately stirred for 15 min. All mixtures were poured on the stainless steel plates before cooling down to temperature of 25°C and subsequently kept in a refrigerator (~4°C) prior to analysis.

Dynamic viscoelastic measurement

Dynamic viscoelastic behaviors of jelly samples were measured by a control stress AR 2000 rheometer (TA Instruments Inc., USA) equipped with a 25 mm parallel steel plate measuring system with 1 mm gap width. An oscillatory frequency sweep assessment was performed using a stress sweep at a constant frequency of 1 Hz and adjusted stress range of 0.01-10 Pa. Consequently, a linear viscoelastic region (LVR) of the samples was determined. A stress of 5 Pa which was the most steady state was chosen for subsequently frequency sweep testing (Figure 1). Storage modulus *(G´)*, loss modulus *(G´´)* and loss tangent (tan $\delta = G''/G'$) were achieved by oscillatory testing over a frequency range of 0.01-20 Hz.

Texture profile analysis

Texture profile analysis (TPA) was carried out using a texture analyzer (TA General, Brookfield engineering Labs Inc., USA) with a 5 kg-load cell. Experiments were evaluated by compression tests which generated plot of force (g) versus time (s). A 38.1 mm diameter TA 4/1000 probe was used to measure the textural profiles of samples.

Color measurement

A colorimeter (HunterLab, ColorFlex, USA) was used with a white plate standard to measure the color parameters of jelly samples. The values of *L* (lightness), a^* (redness) and b^* (yellowness) were measured and then used to calculate the C^* value [C^* (chroma) = $[(a^*)^2 + (b^*)^2]^{1/2}$].

Sensory evaluation

Sensory evaluation was carried out using 90 untrained-panelists. The evaluation method applied a 9-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely). Sensory attributes considered were appearance, color, flavor, taste, texture and overall acceptability. Samples consisted of 2 cm thick slices were served at room temperature.

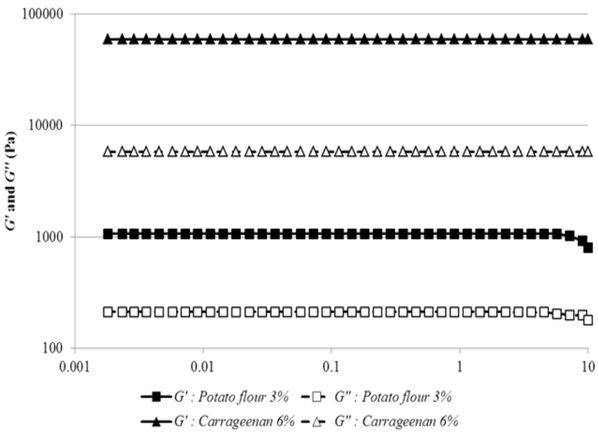

Figure 1. Stress amplitude sweep at frequency 1 Hz for *Chao Kuay* jelly combined with 3% potato flour and 6% carrageenan

Statistical analysis

All data were means with standard deviations (means ± SD). Analysis of variance (ANOVA) was carried out using a SPSS program version 11.5 for Windows (SPSS Inc., USA). Determination of significant differences among treatment means was done by Duncan's multiple range tests (P≤0.05).

Results and Discussion

Rheological behaviors

Oscillatory viscoelastic measurement of storage modulus *(G´)*, loss modulus *(G´´)* and loss tangent (tan δ) are among parameters that characterize the gel system of Chao Kuay jellies. Jiménez-Avalos *et al.* (2005) suggested that *G´* and *G´´* moduli are the measurement of the energy stored and dissipated in the material under test, while tan δ is the ratio of *G´´*/ *G´* and represents the overall viscoelastic nature of the material. Figure 2 and Table 1 depict dynamic viscoelastic behaviors of Chao Kuay jellies added with different levels (3% and 6%) of potato flour (control group), agar and carrageenan. The storage modulus *(G´)* and loss modulus *(G´´)* were plotted against frequency range of 0.01-20 Hz (Figure 2). In all products, *G´* was found much higher than *G´´* and the difference between *G´* and *G´´* of each plot was relatively 1 log cycle, indicating the presence of a solid-like gel with the predominance of an elastic component (Almdal *et al*., 1993). It was noticed that both moduli significantly increased (P≤0.05) with the increasing levels of gelling agents, particularly sample combined with 6% carrageenan. This was probably due to a stronger gel system with more cross-link densities (Apichartsrangkoon and Ledward, 2002; Apichartsrangkoon, 2003). The rising of both *G´* and *G´´* in the jelly samples as affected by the increase of gelling agent levels was an indication

Table 1. Dynamic viscoelastic behaviors measured at a frequency of 1 Hz and texture profile analysis (TPA) of *Chao Kuay* jelly combined with different gelling agents

Gelling agents	Viscoelastic characteristics			Texture profiles				
	G' (Pa)	G'' (Pa)	tan δ	Hardness (g)	Adhesiveness (g.s)	Cohesiveness	Springiness	Gumminess
Potato flour 3%	730.20±4.72^{f}	95.58±6.47^{e}	0.13±0.01^{b}	57.75±1.70^{e}	0.63±0.13^{a}	0.80±0.04^{b}	3.19±0.26^{bc}	47.11±4.86^{e}
Potato flour 6%	1,537.40±36.35^{e}	230.29±17.37^{d}	0.15±0.01^{a}	102.90±4.51^{d}	0.67±0.07^{a}	0.97±0.05^{a}	4.49±0.25^{a}	100.87±3.62^{c}
Agar 3%	11,789.84±44.13^{d}	1,344.63±37.59^{c}	0.11±0.00^{d}	142.41±12.28^{c}	0.00±0.00^{c}	0.71±0.03^{c}	2.20±0.14^{d}	34.73±2.34^{f}
Agar 6%	21,245.69±211.48^{b}	2,498.69±6.89^{b}	0.12±0.00^{c}	2,059.37±128.82^{a}	0.00±0.00^{c}	0.79±0.02^{b}	3.22±0.17^{b}	1,965.13±173.04^{a}
Carrageenan 3%	17,626.61±182.79^{c}	1,354.08±69.04^{c}	0.08±0.00^{f}	144.56±5.97^{c}	0.20±0.04^{b}	0.58±0.07^{d}	2.20±0.13^{d}	80.23±4.58^{d}
Carrageenan 6%	58,660.35±570.64^{a}	5,669.83±141.01^{a}	0.10±0.00^{e}	1,616.65±42.63^{b}	0.51±0.18^{a}	0.71±0.06^{bc}	2.83±0.21^{c}	1,183.65±106.21^{b}

Means in the same column followed the same letters are not significantly different (P>0.05).
Each data point is the average of six replications (n=6).

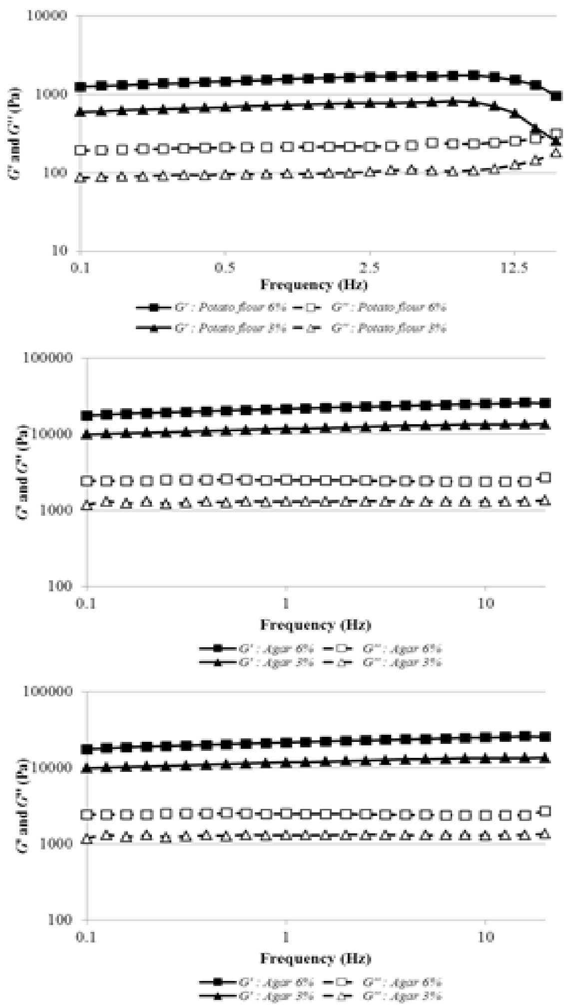

Figure 2. Oscillatory frequency sweeps of *Chao Kuay* jelly combined with different gelling agents

of a true gel behavior structure with more solid-like structure (Ross-Murphy, 1984), confirmed by their loss tangent (tan δ) values which were lower than 0.2 (Table 1). The results were similar to the findings of Satrapai and Suphantharika (2007), who reported that the magnitudes of G' and G'' were increased with the increase of hydrocolloid concentration in freshly prepared gels. In addition, Chaisawang and Suphantharika (2005) found that both G' and G'' values for tapioca starch pastes increased with increasing the gum levels (i.e. guar and xanthan gums). BeMiller (2011) explained that most gels or pastes containing gelling agents (or hydrocolloids) not only usually exhibit higher viscosities, but they also have increased dynamic moduli compared to gels prepared without gelling agents. The increases in dynamic moduli are often not as dramatic as are the increases in viscosity, but they are more indicative of the processes occurring within the gels.

In general, *Chao Kuay* gel was traditionally prepared through an addition of starch to the polysaccharide extract of the plant leaves. The results concerned with the cross-linking of Chao Kuay polysaccharide gum with starch have received particular attention. Lai *et al*. (2000) revealed that the gelling properties and viscoelastic behaviors of this gum were found to be strongly influenced by various factors including extraction conditions, starch types and concentrations as well as parts of the plant.

Texture profiles

Mechanical properties of the *Chao Kuay* jellies were obtained from a texture profile analysis (TPA) test using a texture analyzer. The addition effects of gelling agents on hardness, adhesiveness, cohesiveness, springiness and gumminess of jelly samples were evaluated. Textural parameters obtained from the force time curve were described by Bourne (2002) and Garrido *et al*. (2015). Hardness is defined as the force necessary to attain a given deformation. In sensory analysis, it is the force required to compress a food between molars in the first bite. Adhesiveness represents the work required to pull the compressive probe away from the sample. In sensory analyses, it represents the work necessary to overcome the attractive forces between the surface of the food and the surface of the material with which the food comes into contact. Cohesiveness represents the strength of the internal bonds making up the body of the product. It is expected to be inversely

Table 2. Color attributes of *Chao Kuay* jelly combined with different gelling agents

Gelling agents	Color parameters			
	L	*a**	*b**	*C**
Potato flour 3%	13.91±0.31^{c}	2.23±0.24^{a}	1.14±0.07^{b}	3.51±0.59^{a}
Potato flour 6%	17.41±0.60^{a}	1.74±0.34^{b}	1.60±0.09^{a}	2.85±0.75^{ab}
Agar 3%	14.62±0.25^{b}	0.98±0.06^{c}	-1.14±0.10^{d}	1.14±0.17^{d}
Agar 6%	13.78±0.42^{c}	1.77±0.13^{b}	0.33±0.11^{c}	1.63±0.27^{c}
Carrageenan 3%	14.59±0.46^{bc}	0.76±0.06^{d}	-1.85±0.16^{e}	2.02±0.32^{b}
Carrageenan 6%	13.90±0.32^{c}	0.73±0.08^{d}	-1.83±0.10^{e}	1.95±0.24^{bc}

Means in the same column followed the same letters are not significantly different (P>0.05). Each data point is the average of six replications (*n*=6).

Table 3. Sensory scores of *Chao Kuay* jelly combined with different gelling agents

Gelling agents	Sensory attributes					
	Appearance^{ns}	Color^{ns}	Flavor^{ns}	Taste	Texture	Overall acceptability
Potato flour 3%	7.04±1.24	6.63±1.29	6.27±1.62	6.57±1.68^{a}	6.79±1.70^{a}	6.84±1.33^{a}
Potato flour 6%	6.95±1.52	6.60±1.50	6.35±1.58	6.28±1.52^{ab}	6.12±1.04^{b}	6.03±1.38^{b}
Agar 3%	6.80±1.49	6.42±1.47	6.30±1.53	6.15±1.37^{b}	6.11±1.13^{b}	6.12±1.51^{b}
Agar 6%	6.92±1.60	6.47±1.11	6.28±1.62	6.04±1.47^{b}	5.09±1.07^{c}	5.44±1.50^{c}
Carrageenan 3%	6.75±1.62	6.51±1.27	6.44±1.49	6.02±1.65^{b}	6.20±1.62^{b}	6.01±1.36^{b}
Carrageenan 6%	6.89±1.42	6.40±1.35	6.29±1.44	6.15±1.07^{b}	5.17±1.55^{c}	5.05±1.24^{c}

Means in the same column followed the same letters are not significantly different (P>0.05). Each data point is the average of ninety replications (*n*=6). ns = non significant.

proportional to the rate at which the material fractures under mechanical action. In other words, the lower the cohesiveness of a material, the more brittle it will be. Springiness is related to the height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite. It represents the rate at which a deformed material goes back to its undeformed condition after deforming force is removed. Gumminess represents the energy required to disintegrate a semi-solid food product to a state ready for swallowing.

From this study, it was found that hardness, adhesiveness, cohesiveness, springiness and gumminess values in the products significantly increased (P≤0.05) with increasing concentration of gelling agents, except the adhesiveness values of jelly combined with agar (Table 1). At the high concentration of gelling agents, jelly with 6% agar addition had significant higher (P≤0.05) hardness and gumminess than the other products, while jelly with 6% potato flour addition showed the highest values of adhesiveness, cohesiveness and springiness. However, a low level of potato flour could be appropriate to ensure good textural quality, indicating by the lowest hardness value (57.75±1.70 g). At this concentration, the structure has a medium density of branched-structure (Ross-Murphy, 1984), confirmed by the viscoelastic behaviors (Figure 2 and Table 1), whereas too high concentration of the gelling agents can impair the tastiness of the jelly samples.

Color parameters

Lightness *(L)*, redness *(a*)*, yellowness *(b*)* and chroma *(C*)* were determined for *Chao Kuay* jellies added with various gelling agents including potato flour, agar and carrageenan (Table 2). It was noticed that types and concentrations of gelling agents had a significant effect (P≤0.05) on color parameters of products. In general, jelly combined with 6% potato flour showed significant higher (P≤0.05) *L* (17.41) and b^* (1.60) values than the other batches (*L* = 13.78-14.62, b^* = -1.85-1.14), whereas the highest values of a^* (2.23) and C^* (3.51) parameters in sample added with 3% potato flour were observed. Overall, these results displayed that jelly mixed with 3% potato flour was apparently darker (P≤0.05) than the rest, but this is a good characteristic (dark brown to black in color) for *Chao Kuay* jelly (Lai *et al*., 2000).

Sensory evaluation

Table 3 elucidates sensory attributes including appearance, color, flavor, taste, texture and overall acceptability of *Chao Kuay* jellies combined with 3% and 6% of potato flour, agar and carrageenan. The results showed that an insignificant effect of gelling agents on the appearance, color and flavor scores of jellies was observed (P>0.05), while jelly combined with 3% potato flour had the highest scores of taste, texture and overall acceptability and was significantly differed when compared to the others (P≤0.05). This confirmed that 3% potato flour addition could be appropriate to ensure the good sensory qualities for

Chao Kuay jelly production.

Conclusion

In summary, color parameters indicated that jelly mixed with 3% potato flour was apparently darker than the other samples. The gel had a medium density of branched-structure, suggested by the viscoelastic behaviors. From textural properties and sensory scores, the results confirmed that 3% potato flour addition could be appropriate to ensure the good gel qualities for *Chao Kuay* jelly production.

Acknowledgement

The authors would like to thank the Research and Development Institute, Kamphaeng Phet Rajabhat University for their financial support.

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