The properties of jelly candy made of acid-thinned starch supplemented with konjac glucomannan or psyllium husk powder

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Abstract: In this study, acid-thinned starch was blended with konjac glucomannan or psyllium husk powder at a concentration of 3% w/w (starch basis). The blends were characterized by pasting analysis and rheological properties evaluation. Jelly candy was made from the blends and textural characteristics were studied. Pasting analysis showed that both gums were found to significantly increase some of the pasting parameters, such as peak viscosity, trough, breakdown, final viscosity and setback values. From the frequency sweep, it was found that addition of konjac glucomanan or psyllium husk powder increased the storage modulus (G') and loss modulus (G'') values, with psyllium added sample showing more prominent effect than konjac added ones, when compared to the control samples. All samples were found to demonstrate thixotropic flow behaviour. Jelly candy texture profile analysis revealed that konjac glucomannan or psyllium husk powder addition, although decreasing chewability, but rendered the jelly candy less sticky.

Keywords: starch, psyllium husk, konjac glucomannan, jelly candy

Introduction

Chewy candies are made with different gelling agents and sweeteners that offer characteristic textures and eating properties. The most common chewy candies besides chewing gums are jellies, caramels, nougats and taffies. The vast variety available was invented and developed by confectioners through trial and error without proper investigation. That is why; candy making is commonly recognized as an art rather than as a science, henceforth it is not surprising that literature on candy is relatively scarce.

Jelly candy prepared with acid-thinned starch has a tender yet firm texture. Acid-thinned starch was commonly used due to its high gel strength and capability in inducing rapid set upon cooling (Thomas and Atwell, 1999). Nevertheless, there are problems which are inherent to starch-based foods such as retrogradation, syneresis, and loss of original texture (Ferrero et al., 1996). This can be overcome by blending with hydrocolloids (gums or proteins), which are believed to be able to improve food texture, retard starch retrogradation, enhance moisture retention and overall keeping quality (Stauffer, 1990; Gujral et al., 2004; Lim and Narsimhan, 2006; Muadklay and Charoenrein, 2008; Pongsawatmanit and Srijunthongsiri, 2008; Anton et al., 2009; Tian et al., 2009). In this project, the gums selected to be incorporated into starch-based jelly candy were psyllium husk powder and konjac glucomannan.

Psyllium hydrophilic mucilloid, is a natural fiber derived from psyllium seed husks. It is a highly branched arabinoxylan polysaccharide which has a high water holding and gelling capacity (Anderson et al., 1990). Nowadays, psyllium seed husks are mostly used as dietary supplement to treat constipation, hypercholesterolemia, and for daily colon care (Gerber, 1996; Greenwald et al., 2001; Terry et al., 2001).

On the other hand, konjac glucomannan is a neutral polysaccharide derived from the tubers of *Amorphophallus konjac*. It is an indigestible dietary fiber which helps in weight reduction, cholesterol reduction, and modification of carbohydrate metabolism in diabetics (Imeson, 1997). It was reported to be able to bind bile acids in the gut and carry them out of the body in the faeces thus indirectly making the body converting more cholesterol into bile acids (Wu and Peng, 1997).

To the best of our knowledge, there has been no study conducted to study the addition effect of psyllium or konjac glucomannan on the characteristics of jelly candies despite the fact that, both hydrocolloids have great benefits in terms of nutrition and functional properties. Therefore, this work was devised to study the changes in pasting and rheological properties of acid-thinned starch suspension and paste, respectively. In addition, the keeping quality of the jelly candy

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supplemented with psyllium or konjac glucomannan were evaluated.

Materials and Methods

Materials

Acid-thinned starch (Elastigel 1000 J) was purchased from National Starch and Chemical (M) Sdn. Bhd. (Selangor Darul Ehsan, Malaysia). Konjac glucomannan (KGM) was obtained from Hung Thong Food Technology Sdn. Bhd. (Penang, Malaysia). Psyllium husk (Plantago ovata) (Natural Psyllium Husk, 99.29% purity) was bought from Country Farms Sdn. Bhd. (Selangor, Malaysia). Sugar, corn starch, Tri-sodium citrate, dextrose, citric acid, flavoring agents and coloring agents were obtained from SIM Company Sdn. Bhd. (Penang, Malaysia).

Pasting properties

A Rapid Visco Analyzer (Model RVA Series 4, Newport Scientific Pty. Ltd, Warriewood, Australia) was used to determine the apparent viscosity of starch or starch-hydrocolloid suspension. About 5 g of acid-thinned starch (corrected for 14% moisture basis) was mixed with distilled water in an aluminium canister. Sample without hydrocolloid addition was designated as control. For sample added with hydrocolloid i.e., konjac glucomannan or psyllium husk powder was designated as konjac or psyllium added herein. The level of addition was 3% w/w on starch basis. The starch-hydrocolloid blends were pasted according to a programmed heating and cooling cycle: Sample was first agitated at 960 rpm for 10 sec to impart thorough dispersion, following with holding at 50ºC for 1 min, heating from 50ºC to 95ºC at 12ºC/min and 160 rpm, holding at 95ºC for 2.5 min before cooling to 50ºC at the same stirring rate and lastly holding at 50ºC for 2 min. Pasting parameters such as pasting temperature, peak viscosity, trough, breakdown, final viscosity and setback were determined.

Rheological properties

Rheological evaluation was performed using a rheometer (Model AR 1000, TA Instruments Inc., New Castle, DE, United States). Samples used were those which had been subjected to pasting analysis.

Frequency sweep ranged from 0.01 to 10 Hz was performed at 25°C and at 1% strain which was pre-determined from the linear viscoelastic region of the sample. The geometry used was a 20 mm standard parallel plate and the gap size was fixed at 1000 µm. To avoid evaporation, paraffin oil was wiped over the sample edge. TA Rheologist Data Analysis software (Version 5.4.8) was used to obtain the experimental data and to determine storage modulus (G’) and loss modulus (G’’).

Stepped flow curves were obtained by recording shear stress values when samples were subjected to a programmed shear rate increased linearly from 0 to 1000 s^{-1} and decreased linearly from 1000 to 0 s^{-1}, respectively. All measurements were carried out at 50°C using a parallel plate geometry (40 mm diameter and 1 mm gap).

Making of jelly candy

Three recipes for starch-based jelly candy preparation are shown in Table 1. Acid-thinned starch (Elastigel 1000J) suspension was cooked until

Table 1. Ingredients needed to make jelly candies

Ingredients	Control	Konjac added	Psyllium added
Glucose syrup (42 DE) (g)	360.0	360.0	360.0
Sugar (g)	300.0	300.0	300.0
Dextrose (g)	110.0	110.0	110.0
Acid-thinned starch (g)	100.0	100.0	100.0
Konjac glucomannan (g)	-	3.0	-
Psyllium husk (g)	-	-	3.0
Water (for starch) (g)	550.0	550.0	550.0
Warm water (for citric acid) (ml)	20.0	20.0	20.0
Tri-sodium citrate (g)	4.0	4.0	4.0
Citric acid (g)	4.0	4.0	4.0
Flavoring (g)	1.0	1.0	1.0
Coloring (drop)	1	1	1

Table 2. Pasting properties of acid-thinned starch added with or without konjac glucomannan or psyllium husk.

Pasting Properties	Control	Konjac added	Psyllium added
Pasting Temperature (°C)	77.85 ± 0.43a	78.82 ± 0.51b	77.27 ± 0.23a
Peak Viscosity (RVU)	57.14 ± 0.88a	80.25 ± 3.71b	132.22 ± 3.80c
Trough (RVU)	12.45 ± 0.54a	19.08 ± 3.90b	32.05 ± 6.76c
Breakdown (RVU)	44.69 ± 0.76a	61.17 ± 1.94b	100.17 ± 4.46c
Final Viscosity (RVU)	270.50 ± 9.83a	300.94 ± 12.31b	448.47 ± 37.01c
Setback (RVU)	213.36 ± 9.16a	220.70 ± 12.38a	316.25 ± 35.61b

Table 3. Best-fitted parameters of Herschel-Bulkley model for acid-thinned starch suspension with or without added konjac or psyllium

Sample	Upward curve			Downward curve			Thixotropic area (Pa/s)
	Yield stress (Pa)	Consistency index (Pa.s)	Flow behaviour index	Yield stress (Pa)	Consistency index (Pa.s)	Flow behaviour index	
Control	1.10±1.13a	0.13±0.14a	0.74±0.10b	0.74±0.48a	0.08±0.01a	0.83±0.12a	740.20±180.12a
KGM added	0.47±0.12b	0.06±0.02b	0.85±0.01a	0.60±0.26a	0.08±0.03a	0.84±0.01a	290.23±55.14b
Psyllium added	0.41±0.16b	0.12±0.05a	0.77±0.03b	0.12±0.03b	0.04±0.02b	0.84±0.05a	807.70±177.54a

Note: Mean ± standard deviation of triplicate samples. Values followed by the same letter in the same column are not significantly different (P>0.05).

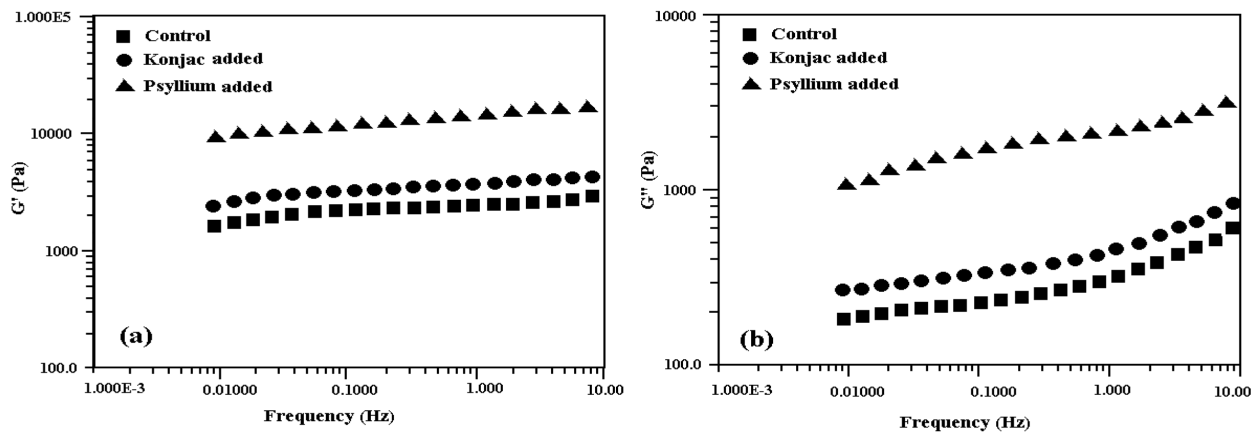

Figure 1. Variation of storage modulus (G') and loss modulus (G") as a function of frequency

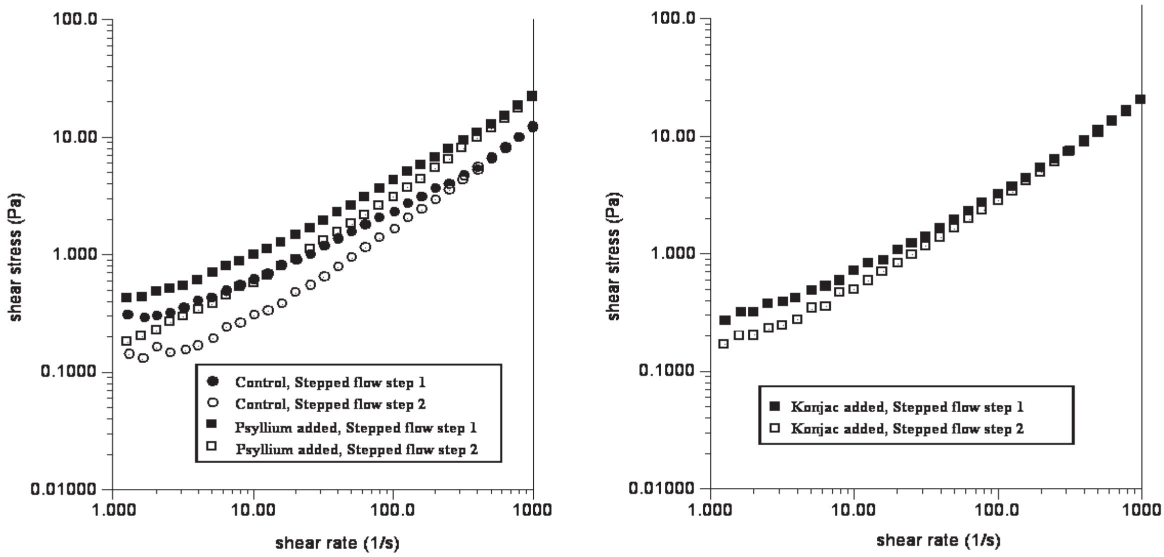

Figure 2. Flow behaviour of acid-thinned starch suspension with or without konjac or psyllium added.

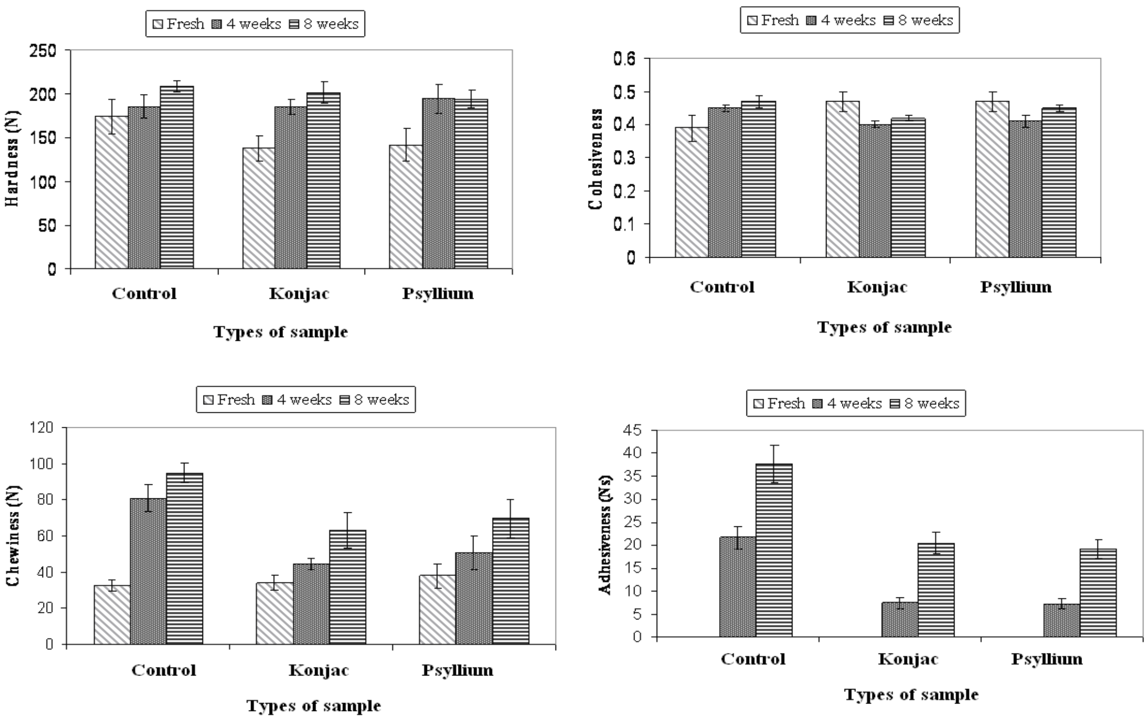

Figure 3. Storage effects on Texture Profile Analysis parameters of different jelly candy prepared.

a clear paste was evident. Where necessary, konjac glucomannan or psyllium powder was pre-mixed with a portion of sugar prior adding into the mixture. After two minutes boiling, glucose syrup was added together with the remaining sugar and dextrose. The mixture was cooked with continuous stirring until a soluble solid content of 65 ºBrix was reached. Lastly, heat was turned off, and citric acid solution, colouring and flavouring agents were added. The suspension was then cast into pre-dried corn starch mould while it was still hot and free flowing. The cast jelly samples were then tempered at 65ºC for 24 hours. Sample preparation was duplicated and samples were stored in air tight container at 30°C and withdrawn at 0, 4 and 8 weeks for texture profile analysis. The abovementioned method was modified from National Starch & Chemical Company's technical notes for jelly candy making.

Texture profile analysis (TPA)

Texture profile analysis (TPA) was performed directly on jelly candies of specific and consistent dimension at ambient temperature with a TA-XT Plus Texture Analyzer (Stable Micro Systems, Surrey, England) using a cylindrical 75 mm diameter probe and a 30 kg load cell. Measurements were conducted at a pre-test speed of 1.0 mm/s, a post-test speed of 10.0 mm/s, a test speed of 2.0 mm/s, and 20 g trigger force. Deformation level was fixed at 75%. Five sub-samples from each sample preparation were analyzed.

Statistical analysis

Statistical analysis was carried out using statistical software SPSS 14.0 for windows (SPSS, Inc., Chicago, IL, USA). Where necessary, One-way ANOVA and Duncan's test were conducted at a significant level of $P < 0.05$.

Results and Discussion

Pasting properties

Pasting properties of acid-thinned starch suspension with or without added konjac or psyllium are reported in Table 2. The pasting temperature was slightly increased with konjac addition and no significant difference was evident for psyllium added sample. Significant differences ($P<0.05$) were recorded in peak viscosities, highest values was shown by psyllium added sample (132.22 RVU), followed by konjac added (80.25 RVU) and control (57.14 RVU). This shows that a higher viscous load would likely to be encountered during cooking of the acid thinned starch suspension with added konjac or psyllium. Such a phenomenon could be attributed to the thickening effect of konjac or psyllium, or alternatively due to interactions happened between gums and swollen starch granules (Rojas and Rosell, 1999) or leached molecules, i.e. amyloses and amylopectins (Shi and BeMiller, 2002; Funami et al., 2005). On the other hand, the gums may provide additional cushion effect to swollen granules to facilitate radial expansion till a maximal swelling capacity is reached.

A higher breakdown value was shown in konjac or pysllium added samples. This value was calculated as the difference between peak viscosity and trough value. Therefore, if the difference in trough values is marginal, the higher the peak viscosity, the higher the breakdown would be recorded. A high breakdown was related to a sample structure that is relatively weaker or less resistant to shearing during heating (Lee et al., 2002).

On cooling, a relatively higher final viscosity and setback values were also shown by konjac or psyllium added sample. This can be attributed to thickening effect of each gum in addition to amylose gelation. According to the work of Alloncle et al. (1989) and Yoshimura et al. (1998), it was suggested that an increase in the effective concentration of starch in the continuous phase could result in an enhanced interaction between amylose molecules. It is the thermodynamic incompatibility between amylose and konjac, and amylose and psyllium polymers that leads to mutual exclusion of each polymers and as a result the local increase in concentration could facilitate molecules rearrangement and association (Allonce and Doublier, 1991; Funami et al., 2005).

Rheological measurements

Frequency sweep. Figure 1 depicts changes of storage modulus (G') and loss modulus (G") of jelly slurries prepared as a function of frequency. In general, a plateau-like graph of G' indicates the presence of network structures (Kulicke et al., 1996). For all samples, G' is predominated over G" and G" increased with increasing frequency, indicating that all samples show gel-like behaviour (Steffe, 1996). From the mechanical spectra, it is clearly evident that psyllium added sample possesses a higher G', hence it is more elastic or solid-like than konjac added and control samples, which may be attributed to a more cohesive network formed among and between psyillium and starch molecules. This observation agrees with those high final viscosity and setback values reported in previous analysis on pasting properties.

Stepped flow analysis. As expected, all samples demonstrated a non-Newtonian shear thinning rheological behaviour (Figure 2). The hysteresis loop shown between the ramp up and ramp down curves indicates that the sample flow was time-dependent. The size of the hysteresis loop is related to the energy needed to destroy the structure responsible for flow time dependence (González-Tomáz et al., 2007). Therefore, the higher the loop area, the more structured the material.

Comparing the three samples tested, the flow curves of psyllium added sample was significantly shifted upwards implying that a relatively higher shear stress is needed to affect a unit flow in psyllium added sample as compared to the others. Result tabulated in Table 3 clearly depicts that konjac added sample shows two to three times smaller thixotropy value. This suggests that konjac may have significantly weakened the network structure of starch molecules, and rendered the blend easier to deform and recover upon removal of shearing load. This in turn explains why lower yield stress and consistency values together with a higher flow behaviour index were evident in sample added with konjac. From the lower yield stress values, it can be anticipated that jelly slurry supplemented with konjac or psyllium is easier to be pumped from the cooker for deposition.

Texture profile analysis (TPA)

The changes of hardness, cohesiveness, chewiness, and adhesiveness of jelly candies prepared are illustrated in Figure 3. The hardness of fresh jelly candy samples tested were found to decrease with addition of konjac or psyllium , but it progressively increased as the samples were stored for 8 weeks at 30°C. The reverse trend was observed for samples cohesiveness. According to Szczesniak (2002), hardness and cohesiveness were defined as the force required attaining a given deformation and the extent to which a material can be deformed before it ruptures, respectively. Hence, these observations suggest that konjac and psyllium are effective in delaying short-term retrogradation. Our result is in line with the work of Funami et al. (2005), which reported that when galactomannan was added to wheat starch, the dynamic mechanical loss tangent of the blend was found to increase during short-term retrogradation, showing that the gelled fraction has been reduced upon addition of gums through inhibition of amylose gelation.

However, for long-term storage post gelation structural rearrangement was accelerated in the presence of konjac or psyllium. Previous explanation may be probably hold here, where the polymer exclusion effect has expedited the retrogradation process between amylose and amylopectin molecules. Consequently, a highly rearranged or organized starch gels resulted and the texture became harder and less deformable upon long-term storage.

On the other hand, chewiness which is defined as the energy required masticating a solid food to a state ready for swallowing (Szczesniak, 2002), was shown to increase with storage time, however the intensity of increment is reduced substantially upon addition of konjac or psyllium. This is consistent with the result of springiness (data not shown), at which a less springy gels were demonstrated by konjac or psyllium added jelly candies. In other words, konjac and psyllium addition rendered the acid-thinned starch jelly less chewable.

As evident in Figure 3, the attributes of adhesiveness was not shown in all fresh samples, but it appeared after storage. It increased significantly higher in the control samples than gums added ones. This indicates that konjac or psyllium helps to enhance the water holding capacity of acid-thinned starch jelly candy.

Conclusions

This study showed that konjac and psyllium at relatively small amount can modify the physical performance of acid-thinned starch in jelly candy production. From the results obtained, though konjac or psyllium was found to produce a higher viscous starch suspension during cooking, the jelly slurry prepared can be pumped easily during deposition with a relatively lower yield stress value, when compared with the control sample. Apart from this, gums addition enhanced the water holding capacity of acid-thinned starch jelly candy. Overall, the jelly candy quality characteristics supplemented with konjac or psyllium were found to be acceptable with reduced stickiness.

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