Agriculture and Natural Resources 52 (2018) 298–304

Contents lists available at ScienceDirect

Agriculture and Natural Resources

journal homepage: http://www.journals.elsevier.com/agriculture-and-natural-resources/

Original Article

Modified quality of seasoning syrup for coating and enhancing properties of a food model using xanthan gum

Duenchay Tunnarut, Rungnaphar Pongsawatmanit*

Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok, 10900, Thailand

ARTICLE INFO

Article history:
Received 27 September 2017
Accepted 25 June 2018
Available online 20 July 2018

Keywords:
Hydrocolloids
Rheological properties
Snack
Syrup pickup
Xanthan gum

ABSTRACT

In the food industry, the quantity of seasoning syrup coating on the food surface plays an essential role in determining final product quality. The effect was investigated of xanthan gum (Xan; 0%, 0.1%, and 0.2%) on the rheological properties of seasoning syrups (35% and 45% sucrose) at different temperatures (25 °C, 35 °C, 45 °C, and 55 °C). The syrups containing Xan exhibited shear-thinning behavior ($n < 1$). The syrup viscosity increased with increasing Xan and sucrose concentrations but decreased with temperature. A regression model was developed for predicting syrup viscosity from Xan, sucrose, and temperature and showed good predictability. A dried, thin-sheet squid sample was used as a snack model for syrup coating. The syrup pickup increased as a function of the viscosity and approach plateau after 300% pickup. Xan enhanced the amount of syrup coating and total soluble solids ($p < 0.05$) but the water activity and moisture content values did not differ significantly ($p > 0.05$) among the samples with and without Xan. The results indicated that Xan could be used in the food industry to enhance the quality of syrup in terms of the viscosity for syrup pickup and the final quality of the product.

Introduction

A syrup coating on the surface of the food is usually used to enhance the taste of final products. The coating created as a layer on the food surface can extend the shelf life of a snack by reducing the migration of moisture, flavor loss and oxidation of the core constituents because the coating layer provides a barrier to the movement of moisture, oxygen, and volatiles. Moreover, the coating could improve flavors, taste and maintain the structural integrity of the product (Fellows, 2009; Pavithra et al., 2013). The seasoning syrup containing many ingredients such as salt, citric acid, color or flavor, is widely used in the snack industry. The syrup viscosity is important to determine the amount of syrup coating on the food surface including the final product quality. Sugars are widely used for enhancing the sweetness and viscosity in the syrup (Wang et al., 2014). Hydrocolloids are one of the ingredients used for enhancing the viscosity, thickening, and stability (Willams and Phillips, 2009; Pongsawatmanit et al., 2011) by modifying the rheological properties of the syrup. The mixture of sugars and hydrocolloids contributes to the properties of the syrup such as sweetness, textural attributes (mouth-feel properties) and rheological properties (Hansson et al., 2001). The viscosity of syrups depends on the types and concentrations of hydrocolloids and sugars (Molina-Rubio et al., 2010).

Xanthan gum (Xan) is an anionic microbial heteropolysaccharide produced by *Xanthomonas campestris*. Xan is reported to provide excellent stability in thermal and acid systems and enhances viscosity stability (Pongsawatmanit et al., 2013; Wang et al., 2016) in many food products, for example, cake, condiment and beverage products. Xan has been used to increase the viscosity of blueberry syrup (Pongsawatmanit et al., 2011) and the syrup prepared from date syrup and sesame paste (Razavi et al., 2007). However, the syrup used for seasoning or coating on the surface of the food is widely applied in the snack industry and the temperature dependence of viscosity plays an important role in the amount of syrup pickup during production. Xan is used in the syrup for coating not only because of its high viscosity and thermal stability but also because of the high yield stress of Xan in the aqueous system (Williams and Phillips, 2003; NPCS Board of Consultants and Engineers, 2009). At very low shear rates, the suspended particles could remain stationary due to the very high viscosity of the solutions containing Xan below the yield point. Then, after dip-coating, the coated syrup layer remains stuck on the product surface (Maillard et al., 2016). These characteristics of Xan are some of its advantages in adding to the syrup for coating compared to other hydrocolloids by reducing the amount of syrup dropping out from

* Corresponding author.
E-mail address: fagiruw@ku.ac.th (R. Pongsawatmanit).

https://doi.org/10.1016/j.anres.2018.06.012

the surface after coating. Therefore, in this study, the quality modification of seasoning syrup using Xan was investigated in terms of steady-shear viscosity at different temperatures and syrup pickup. Regression analysis was used to predict the viscosity based on Xan, sucrose and the temperature. The dried, thin squid (1 mm thickness) was used as a snack food model for coating. The quality of seasoned, thin-sheet squid was also determined after coating and drying.

Materials and methods

Materials

Xan (CP Kelco, San Diego, CA, USA) and sucrose (white sugar, Mirtphol, Suphan Buri, Thailand) were obtained and used without any further modification. Maltodextrin with 10–12 dextrose equivalent (DE) (5.9% wet basis) (Zhucheng Dongxiao Biotechnology Co., Ltd, Dongxiao, China), citric acid (Ajax Finechem, Melbourne, Australia), sodium tripolyphosphate (STPP) (Chemipan, Thailand) were used for syrup preparation. Salt, soy sauce, chili powder and monosodium glutamate (MSG) were purchased from a local supermarket in Bangkok, Thailand.

Preparation of seasoning syrup and dried seasoned food model

Seasoning syrup samples were prepared with and without Xan (0%, 0.1%, and 0.2%) and sucrose (35% and 45%). From preliminary experiment, the addition of Xan >0.2% in the syrup resulted in very high viscosity with high syrup pickup on the food model surface and difficulty in drying off. The syrups containing 35% and 45% sucrose provided a good coating on the food model surface for the systems with and without Xan. The syrups containing Xan and a sucrose content >45% were also found to create a thick layer of coating leading to a longer drying time and dried sticky products with a dark-brown color. Each formulation consisted of other ingredients with fixed percentages of 5% maltodextrin, 2.9% dry ingredients (salt, monosodium glutamate, sodium tripolyphosphate (STTP), chili powder and citric acid), 5% soy sauce and water.

The syrup (300 g) was prepared for each formulation. For Xan dispersion, Xan was mixed with a part of the sucrose, dispersed in the water and stirred continuously for 30 min using a magnetic stirrer (model M21/1; Framo-Gerätetechnik; Eisenbach, Germany). Other dry ingredients except for the chili powder and citric acid were then mixed at room temperature for 2 min prior to adding into the Xan dispersion or water (for syrup without Xan) and further mixed for 3 min. Each mixture was heated to 72 ± 2 °C before adding soy sauce and chili powder and then was further heated until boiling when the citric acid was finally added. Steady shear viscosity at 25 °C, 35 °C, 45 °C, and 55 °C was measured and the syrup pickup at 55 °C was determined.

A sample (50 ± 2 g per batch) of dried, thin squid (1 mm thickness, about 1 g/piece) for each replication was dipped into the seasoning syrup (55 °C) for 2 min. The ratio of food to syrup used was 1:4 (weight per weight; w/w). The excess syrup on the surface was allowed to drip off for 2 min at room temperature. The coated seasoned food model was then dried in a conventional tray dryer at 90 °C for 3–5 h to obtain dried seasoned squid with a final moisture content of about 3.2–4.5% (wet basis) depending on the Xan concentration. The quality of the dried, seasoned squid was determined.

Quality measurement of seasoning syrup

The steady shear viscosity of the seasoning syrups with and without Xan (0–0.2%) and sucrose (35% and 45%) was measured as a function of the shear rate and ranged from 1.17 to 100 1/s at 25 °C, 35 °C, 45 °C and 55 °C using a rheometer (Physica MCR 300; Anton Paar GmbH; Stuttgart, Germany) with concentric cylinder geometry (CC27) and a bottom plate (TEZ150P). Sample temperatures were kept constant for at least 5 min before measurement.

The shear stress and shear rate of seasoning syrups with different concentrations of Xan and sucrose were plotted to describe the behavior of the fluids which was evaluated using the power law model as shown in Equation (1):

$$\tau = K\dot{\gamma}^n \quad (1)$$

where τ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (1/s), K is the consistency coefficient (Pa.s^n) and n is the flow behavior index (Steffe, 1996; Ketjarut et al., 2010).

The effect of temperature on the viscosity at a shear rate of 53 1/s was also calculated using the Arrhenius equation shown in Equation (2):

$$\ln \eta_a = \ln \eta_\alpha + [E_a/RT] \quad (2)$$

where η_a is the viscosity at the specific shear rate, η_α is the frequency factor, E_a is the activation energy (J/mol), R is the gas constant (J/mol K) and T is the absolute temperature (K).

Syrup pickup refers to the quantity of syrup adhering to the surface of the food after dipping. Dried, thin squid samples (50 ± 2 g) were dipped into each seasoning syrup (55 °C) for 2 min (dried squid: syrup = 1:4) and was allowed to drip for 2 min before weighing (modified from Ketjarut and Pongsawatmanit, 2015). The syrup pickup was calculated as the percentage of the syrup weight compared to the initial weight of the dried squid. The measurements were taken in triplicate.

Determination of snack model quality

The quality of the seasoned squid samples after drying was evaluated. The quantity of coating after drying was calculated as the percentage of the weight of the syrup solid after drying compared to the initial weight of the thin-sheet squid before coating.

The water activity (a_w) of each sample was determined at 25 °C using a water activity instrument (AquaLab Pre; Pullman WA, USA). After equilibration, the a_w value was recorded. Saturated salt solutions of LiCl, $MgCl_2$, and $MgNO_3$ with a_w values at 25 °C of 0.113, 0.328 and 0.529, respectively, were used for instrument validation before measurement (modified from Chaethong and Pongsawatmanit, 2015). The moisture content of each sample (3 g) was determined using a hot air oven (WTB Binder; Tuttlingen, Germany) at 105 °C for 6 h or until a constant weight was obtained (modified from AOAC, 2000).

The TSS was determined using a refractometer (Atago; Tokyo, Japan) by mixing smaller pieces of snack model with deionized distilled water and stirring continuously for 30 min using a magnetic stirrer before measurement and calculating the value using a dilution factor.

Statistical analysis

All measurements were performed with at least three replications. The results were reported as the mean value ± standard deviation. The experiment used a two-way factorial treatment arrangement with two factors (Factor 1: Xan concentrations, and Factor 2: sugar concentrations) using a complete randomized design. The data were subjected to analysis of variance using the SPSS V.12 statistical software package (SPSS (Thailand) Co., Ltd.) and Tukey's range test for determining significant differences (alpha = 0.05). The Pearson's correlation matrix between the influence of Xan, sucrose, and temperature on *K* and *n* obtained from the power law model and viscosity of the seasoning syrup was evaluated. A linear regression was performed to relate the viscosity with the Xan, sucrose, and temperature for predicting a set of response/dependent variables. A correlation matrix between the influence of Xan and sucrose on syrup pickup, TSS, a_w and the moisture content for dried seasoned food model was also performed.

Results and discussion

Quality of seasoning syrup

The viscosity was investigated as a function of the shear rate ranging from 1.17 to 100 1/s of seasoning syrup (35% and 45%) with and without Xan (0–0.2%) at 25 °C, 35 °C, 45 °C, and 55 °C. The viscosity of all syrups increased with increasing Xan and sucrose contents at the same shear rate. The viscosity of syrups containing Xan had higher values than those without Xan (Fig. 1). These results were in good agreement with those observed in blueberry syrup (Pongsawatmanit et al., 2011). The viscosity of the syrups containing Xan (0.1% and 0.2%) decreased with increasing shear rate (1.17–100 1/s) (Fig. 1) revealing shear-thinning behavior. The rheograms (plot of shear stress as a function of shear rate) of seasoning syrups prepared from different Xan concentrations (0%, 0.1%, and 0.2%) and sucrose (35% and 45%) were plotted (data not shown). The power law in Eq. (1) could be used to describe the flow behaviors of all syrups with different Xan and sucrose contents at different temperatures due to the good coefficient of determination (r^2 > 0.973). The consistency coefficient (*K*) values of seasoning syrup without Xan were the lowest (0.01–0.04 Pa.s^n, Fig. 2) for all studied temperatures. The *K* values increased with increasing Xan contents ($p < 0.05$) but decreased with increasing temperature. The addition of Xan in the syrups altered the flow behavior index (*n*) of the syrups without Xan from Newtonian ($n \cong 1$) to Non-Newtonian behavior (*n* about 0.43–0.52 and 0.32–0.40 for syrups containing 0.1% and 0.2% Xan, respectively, Fig. 2, $p < 0.05$). The results suggested that Xan could be used to enhance the viscosity of the syrups and modify the flow behavior to be more pseudoplastic (shear-thinning) in the syrups.

Pearson's correlation coefficients (*r*) were used to quantify the relationship between two variables on a scatterplot for the strength

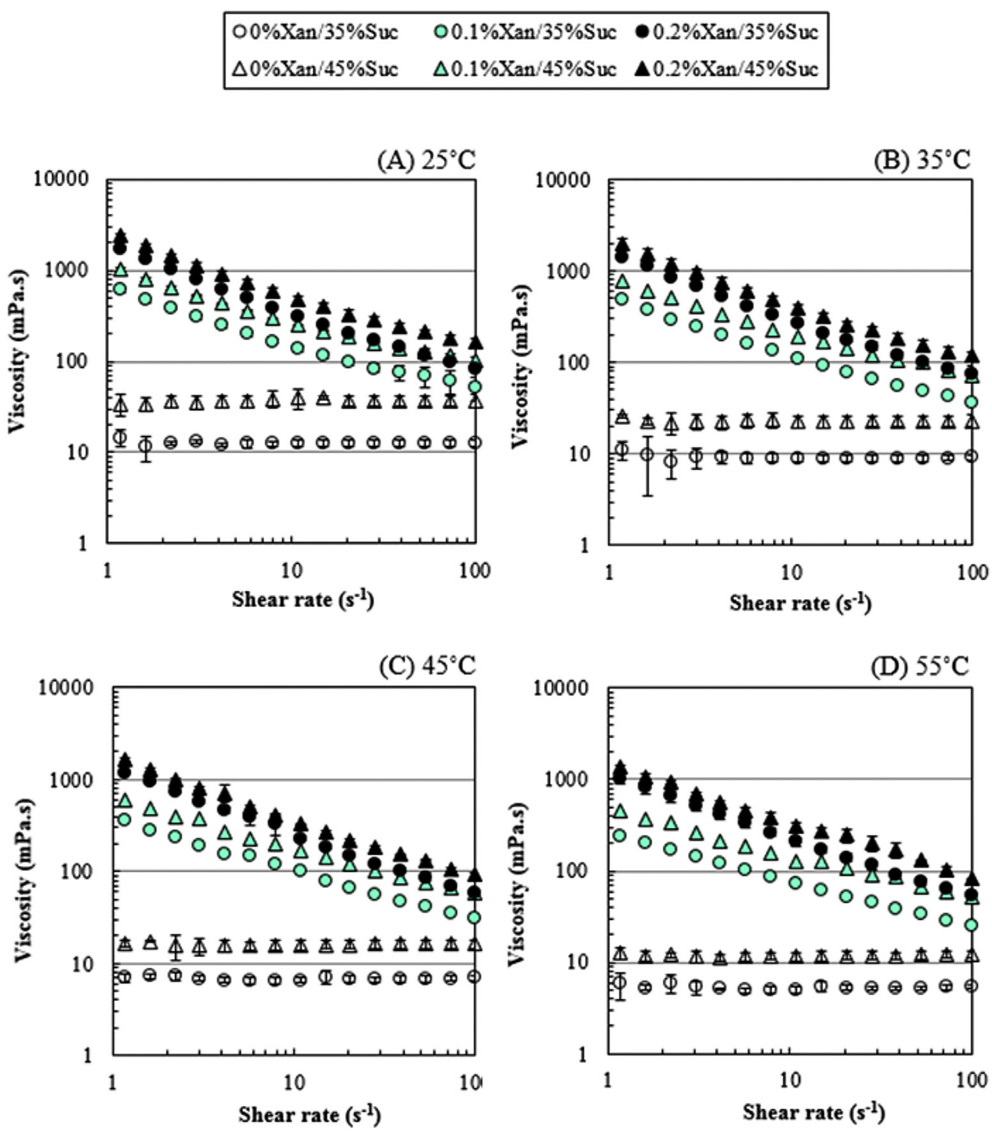

Fig. 1. Viscosity of syrup containing different concentrations of Xan (0%, 0.1% and 0.2%) and sucrose (35% and 45%) determined at: (A) 25 °C; (B) 35 °C; (C) 45 °C; (D) 55 °C. The measurement was performed at shear rates from 1.17 to 100 1/s.

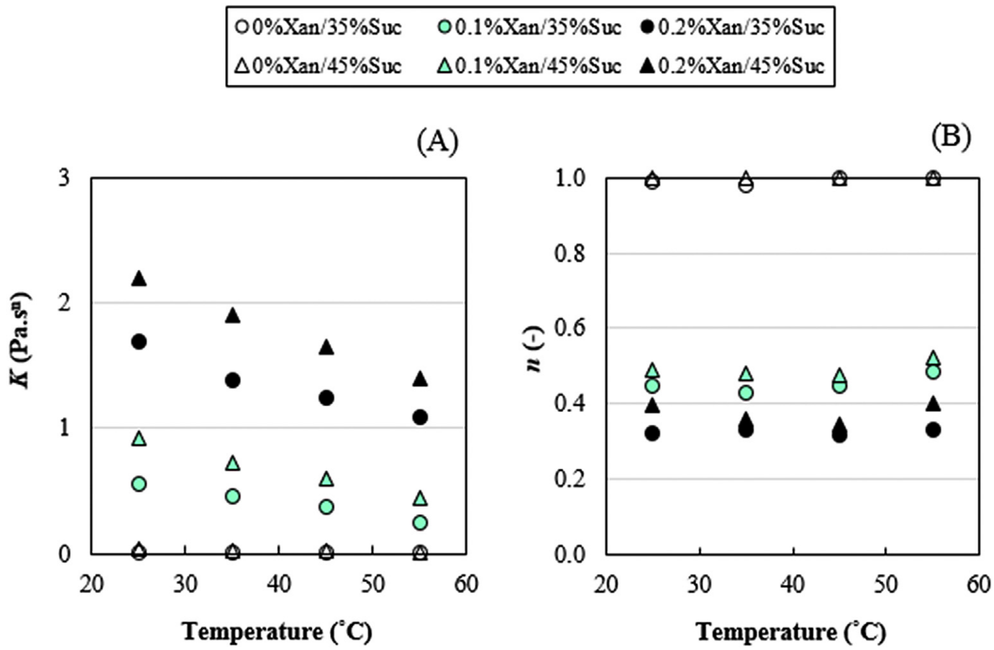

Fig. 2. Consistency coefficient (K) (A) and flow behavior index (n) (B) from power law model of syrups containing Xan (0%, 0.1%, and 0.2%) and sucrose (35% and 45%) as a function of temperature.

and direction of the linear relationship. The relationships were evaluated between Xan, sucrose, temperature, K and n parameters from the power law, and syrup viscosity. Xan had strong positive correlations for K (0.920) and viscosity (0.829) and negative correlations for n (−0.936; Table 1, $p < 0.05$). Sucrose and temperature had moderate correlations ($r \approx 0.4$ and −0.3, respectively, $p < 0.05$) for syrup viscosity (Taylor, 1990). However, a nonsignificant weak correlation ($r = 0.058$, $p > 0.05$) of sucrose and n was observed and could be explained by the syrup exhibiting Newtonian fluidity even at a high sucrose concentration (55%, data not shown).

Since the syrup viscosity is important for determining the quality of the coated product, linear regression analysis was conducted to predict the response/dependent variable (Y: *viscosity*) from a set of explanatory/independent variables (X: *Xan, sucrose*, and *temperature*) as shown in Equation (3) below:

$$\text{Viscosity} = -91.217 + 551.875(\text{Xan}) + 4.072(\text{Sucrose}) - 1.384(T) \quad (3)$$

where Xan is the xanthan gum concentration (0%, 0.1%, and 0.2%), sucrose is the sucrose concentration (35% and 45%) and T is the temperature (25 °C, 35 °C, 45 °C and 55 °C).

The model performance was tested using another group of experimental data of viscosity with newly prepared seasoning syrup containing different Xan and sucrose concentrations measured at 25 °C, 35 °C, 45 °C, and 55 °C. Then, the experimental viscosity values were plotted against the predicted values calculated using Eq. (3) (Fig. 3). The syrup viscosity with different Xan and sucrose concentrations at various temperatures had good predictability between the dataset from the experiment and the model. The corresponding correlation coefficient ($r = 0.961$) and root mean square error value (RMSE = 15.632) between both datasets were obtained.

The viscosity of all syrups decreased with increasing temperature (25–55 °C) (Fig. 1). The viscosity at a shear rate = 53 1/s was selected to plot against the syrup temperature (modified from Ketjarut et al., 2010) because the reading value could be obtained directly from the rheometer. The viscosity clearly decreased with increasing temperature for each syrup combination (Fig. 4A). The influence of temperature on the syrup viscosity was estimated using the Arrhenius equation in Eq. (2) by plotting ln η_a as a function of 1/T (Fig. 4B); the changes in viscosity for all syrups with different Xan and sucrose contents followed the Arrhenius model with a coefficient of determination (r^2) > 0.91. The slopes of the plots were used to determine the activation energy (E_a), reflecting the sensitivity of the viscosity to temperature. The E_a values of the syrups without Xan ($p < 0.05$) were 24 kJ/mol and 30 kJ/mol for 35% and 45% sucrose, respectively. However, the E_a values of syrups containing 0.1% and 0.2% Xan were 18–21 and 12–13 kJ/mol,

Table 1
Correlation matrix between Xan, sucrose, temperature, consistency coefficient (K), flow behavior index (n), and syrup viscosity at a shear rate at 53 1/s. Syrups containing Xan (0%, 0.1% and 0.2%) and sucrose (35% and 45%) were measured at 25 °C, 35 °C, 45 °C and 55 °C.

	Xan	Sucrose	T	K	n	Viscosity at 53 1/s
Xan	1.000					
Sucrose	0.000	1.000				
T	0.000	0.000	1.000			
K	0.920*	0.177	−0.197	1.000		
n	−0.936*	0.058	−0.017	−0.795*	1.000	
Viscosity at 53 1/s	0.829*	0.374*	−0.285*	0.940*	−0.742*	1.000

*Correlation is significant at the 0.05 level (2-tailed), $p < 0.05$. T = temperature.

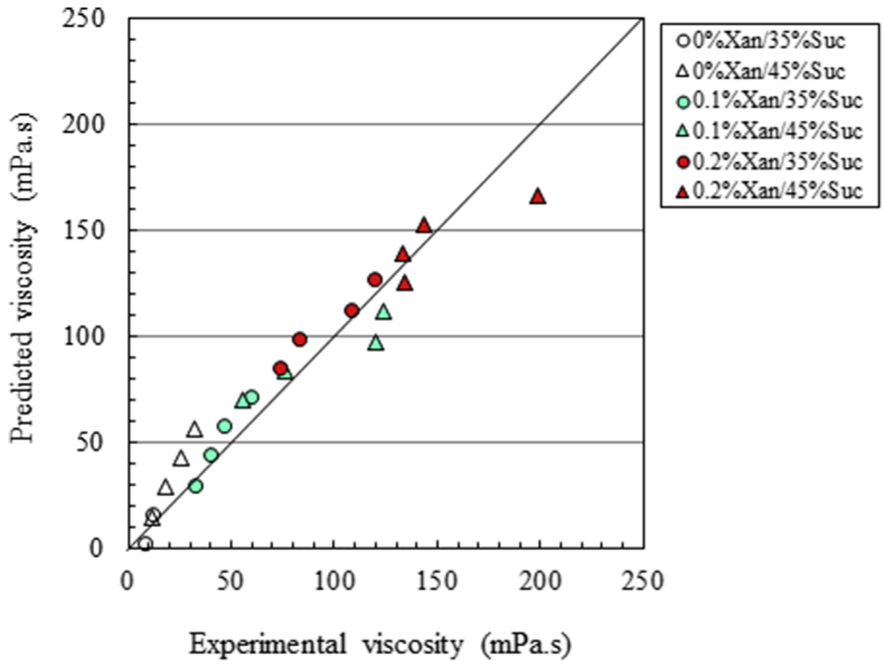

Fig. 3. Predicted viscosity at 53 1/s shear rate using Eq. (3) and experimental viscosity from syrups containing Xan (0%, 0.1% and 0.2%) and sucrose (35% and 45%) for all temperatures (r = 0.961, RMSE = 15.632).

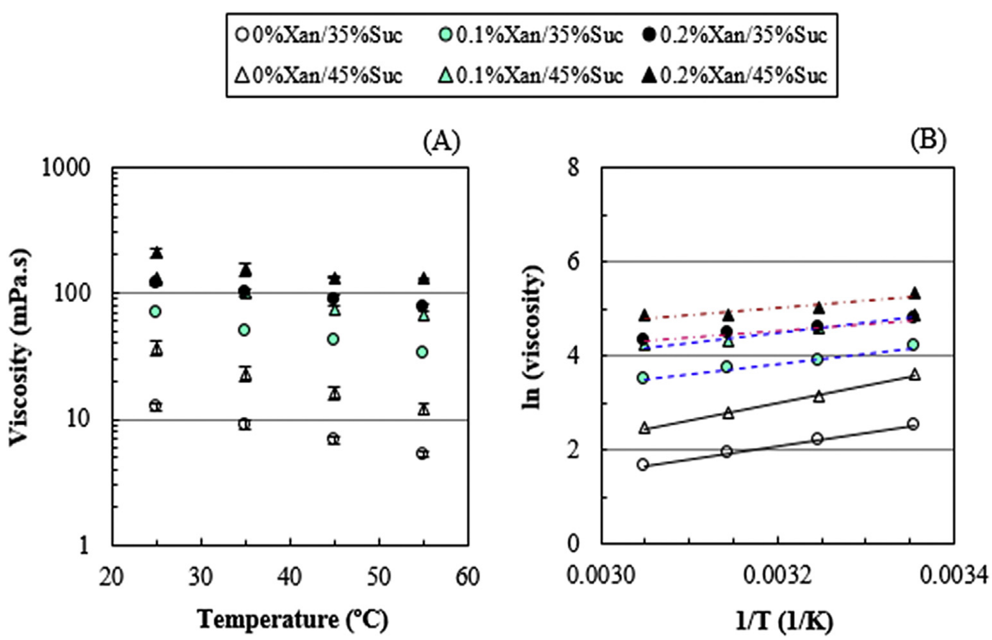

Fig. 4. Temperature dependence at 53 1/s selected shear rate of (A) viscosity and (B) and Arrhenius plot of syrups containing different Xan concentrations (0%, 0.1%, and 0.2%) and sucrose (35% and 45%).

respectively (Table 2). The E_a did not differ significantly between the syrups containing 35% and 45% sucrose. The results indicated that Xan addition not only increased the syrup viscosity but also the thermal stability of the syrups.

Since the amount of seasoning syrup coating on the food surface plays an important role in the properties of the final product, the dried, thin squid with 1 mm thickness was used as a snack model for syrup coating. The syrup pickup increased with increasing Xan and sucrose contents (Table 2, $p < 0.05$) due to the higher viscosity in the syrup containing Xan and sucrose. The pickup values of syrups without Xan were about 154–196% for syrup containing 35–45% sucrose, respectively. The pickup increased significantly ($p < 0.05$) to 256–279% and 309–319% for 0.1% and 0.2% Xan addition (Table 2). When the syrup pickup was plotted as a function of syrup viscosity (selected at a shear rate of 53 1/s, 55 °C), a logarithmic relationship (r^2 = 0.973) was observed for all studied syrups with different Xan and sucrose contents (Fig. 5) and is shown in Equation (4):

$$\text{Syrup pickup}(\%) = 52.755 \ln(\text{viscosity}) + 67.204 \quad (4)$$

Table 2
Activation energy (E_a) derived from the Arrhenius model plot (Fig. 4B), syrup pickup on food model surface and the quality of the final dried seasoned product.

Xan (%)	Sucrose (%)	E_a (kJ/mol)	Syrup pickup at 55 °C (%)	Dried syrup solid (%)	Water activity (−)	Moisture content (%, wb)	TSS (°Brix)
0	35	23.5 ± 1.7^{ab}	154 ± 11^{e}	93 ± 3^{d}	0.319 ± 0.008^{b}	3.16 ± 0.09^{b}	73.4 ± 0.3^{e}
	45	30.0 ± 1.4^{a}	196 ± 4^{d}	144 ± 15^{c}	0.326 ± 0.004^{b}	3.37 ± 0.11^{b}	75.2 ± 0.3^{d}
0.1	35	18.3 ± 3.5^{bc}	256 ± 8^{c}	179 ± 11^{b}	0.322 ± 0.003^{b}	3.20 ± 0.28^{b}	80.2 ± 0.3^{c}
	45	20.6 ± 2.2^{b}	279 ± 13^{b}	205 ± 13^{b}	0.333 ± 0.009^{ab}	3.42 ± 0.34^{b}	81.4 ± 0.3^{b}
0.2	35	11.9 ± 3.3^{c}	309 ± 4^{a}	198 ± 7^{b}	0.336 ± 0.019^{ab}	3.22 ± 0.12^{b}	81.1 ± 0.3^{b}
	45	13.3 ± 2.0^{c}	319 ± 6^{a}	254 ± 14^{a}	0.361 ± 0.029^{a}	4.45 ± 0.64^{a}	83.9 ± 0.2^{a}

Wb = wet basis; Mean ± standard deviation values (n = 3 for E_a, syrup pickup and dried syrup solid; n = 6 for water activity; n = 6 for moisture content, and n = 9 for total soluble solids (TSS) followed by a different lowercase letter within the same column are significantly different ($p < 0.05$) using Tukey's range test.

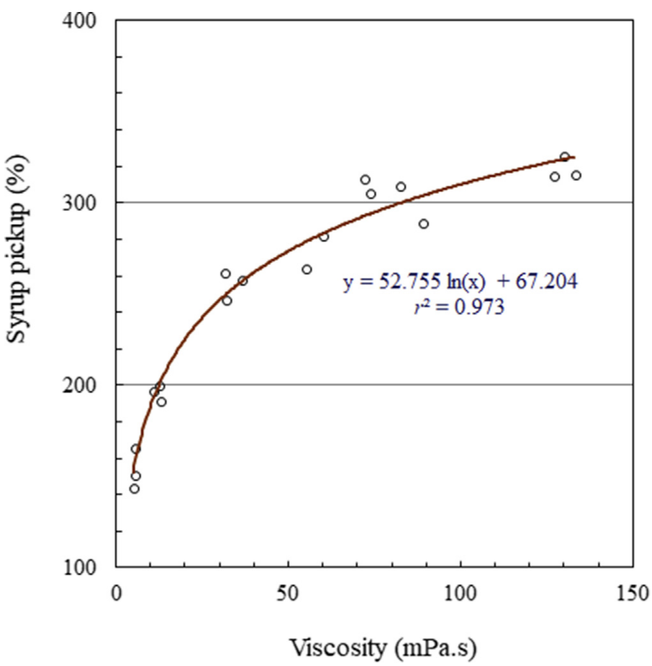

Fig. 5. Syrup pickup (at 55 °C) on a surface of snack model as a function of syrup viscosity. The viscosity of syrups containing Xan (0%, 0.1% and 0.2%) and sucrose (35% and 45%) at 55 °C was used and evaluated with a shear rate of 53 1/s ($r^2 = 0.973$).

The pickup increased sharply at the low syrup viscosity and then began to approach a maximum value after pickup of more than 300%. The results indicated that there was a limit value of syrup pickup on the food surface.

Quality of dried seasoned snack model

The dried squid with 1 mm thickness was used for syrup coating. The moisture content and water activity of the dried squid were 20.7 ± 0.3% (wb) and 0.700 ± 0.000, respectively. After coating and drying, the quality of the dried seasoned samples was determined. The amount of coating after drying (dried syrup solid) is a parameter representing the syrup solid adhering to the surface of the food after drying and relates to final product properties such as the a_w, moisture content and total soluble solids (TSS) values. The amount of dried syrup solid increased with increasing Xan and sucrose concentrations due to the higher syrup pickup. Without Xan in the syrup, the percentages of dried syrup were 93–144% compared with the original weight of dried, thin-sheet squid prior to coating. The samples prepared from syrups containing 0.1% and 0.2% Xan had higher percentages of dried syrup on the surface with 179–205% and 198–254%, respectively (Table 2). Higher dried syrup solid was observed in the samples containing a higher sucrose content (45%). The results suggested that Xan addition in the seasoning syrup increased the yield of the final product expected from the higher viscosity and pickup prior to drying.

The a_w correlated with the stability of food related to the chemical reactions and microbial growth. The a_w values were about 0.319–0.336 (Table 2, $p > 0.05$) for the products with and without Xan except that prepared from 0.2% Xan and 45% sucrose ($a_w = 0.361$, $p < 0.05$). The higher a_w was expected from the higher syrup pickup and dried syrup solid due to the high viscosity of the syrup containing 0.2% Xan and 45% sucrose. The same trend was also observed in the moisture contents of all dried snack products. The moisture contents of the snack did not differ significantly (about 3.16–3.42%) (Table 2, $p > 0.05$) for the products with and without Xan, except for the samples with 0.2% Xan and 45% sucrose which had the highest moisture content (4.45%), $p < 0.05$). However, further investigations to describe the coating properties preventing weight and flavor loss of the seasoned snack products during storage should be carried out.

The TSS values of the products were about 73.4–83.9°Brix and increased with increasing Xan and sucrose contents (Table 2, $p < 0.05$). The lowest TSS (73.4°Brix) sample was obtained with the syrup (35% sucrose) without Xan and the highest TSS (83.9°Brix) sample was prepared from the syrup with 0.2% Xan and 45% sucrose. The results indicated that the higher syrup pickup enhanced the TSS of the snack product but there was not a significant difference between the a_w and moisture content. Therefore, Xan could be used to increase the yield of the product due to the higher syrup viscosity without altering the a_w of the samples.

Pearson's correlation coefficients (r) were also used to quantify the relationship between Xan, sucrose, syrup pickup, TSS, a_w and moisture content. The results confirmed that Xan had significant, strong, positive correlations for syrup pickup ($r = 0.948$, Table 3),

Table 3
Correlation matrix between pickup, total soluble solids (TSS), water activity (a_w) and moisture content of product containing various concentrations of Xan (0%, 0.1% and 0.2%) and sucrose (35% and 45%).

	Xan	Sucrose	Syrup pickup	TSS	a_w	Moisture Content
Xan	1.000					
Sucrose	0.000	1.000				
Syrup pickup	0.948*	0.208	1.000			
TSS	0.909*	0.261	0.968*	1.000		
a_w	0.553*	0.380	0.655*	0.560*	1.000	
Moisture content	0.432*	0.518*	0.520*	0.495*	0.536*	1.000

*Correlation is significant at the 0.05 level (2-tailed), $p < 0.05$.

TSS ($r = 0.909$), and had moderate correlations for a_w and moisture content ($r = 0.553$ and 0.432, respectively, $p < 0.05$). Syrup pickup had a positive correlation for TSS ($r = 0.968$), and exhibited moderate correlations for a_w ($r = 0.655$) and moisture content ($r = 0.520$, $p < 0.05$) suggesting the amount of syrup pickup was related to the final properties of the products.

In conclusion, the addition of Xan could modify the quality of seasoning syrup to produce higher viscosity and syrup pickup with more thermal stability in viscosity than in syrups without Xan. The hydrocolloid changed the flow behavior of the syrups from Newtonian to shear-thinning fluids. The developed regression model for predicting syrup viscosity from Xan, sucrose and temperature exhibited good predictability. Xan enhanced the yield of the snack model by increasing the amount of syrups coating. Therefore, Xan could be used to prepare the syrup for coating to enhance the qualities of syrup and final, dried seasoned product in the food industry. The information gained in this study will help improve understanding of the role that the coating plays in preserving the quality of dried squid.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

The first author was supported by the Thailand Research Fund (TRF) under the Research and Researchers for Industries (RRI) project (Grant No. PHD 56I0022). The study was based upon work partially supported by the Kasetsart University Research and Development Institute (KURDI).

References

AOAC, 2000. Official Methods of Analysis of AOAC International, seventeenth ed. The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Chaethong, K., Pongsawatmanit, P., 2015. Influence of sodium metabisulfite and citric acid in soaking process after blanching on quality and storage stability of dried chili. J. Food Process. Preserv. 39, 2161–2170.

Fellows, P.J., 2009. Food Processing Technology: Principles and Practice, third ed. CRC Press, Boca Raton, FL, USA.

Hansson, A., Andersson, J., Leufvén, A., 2001. The effect of sugars and pectin on flavor release from a soft drink-related model system. Food Chem. 72, 363–368.

Ketjarut, S., Pongsawatmanit, R., 2015. Influence of tapioca starch on thermal properties of wheat flour-based batter and quality of fried battered chicken wingsticks. Int. J. Food Eng. 11, 641–650.

Ketjarut, S., Suwonsichon, T., Pongsawatmanit, R., 2010. Rheological properties of wheat flour-based batter containing tapioca starch. Kasetsart J. (Nat. Sci.) 44, 116–122.

Maillard, M., Bleyer, J., Andrieux, A.L., Boujlel, J., Coussot, P., 2016. Dip-coating of yield stress fluids. Phys. Fluids 28, 53102–53102.

Molina-Rubio, M.P., Casas-Alencáster, N.B., Martinez-Padilla, L.P., 2010. Effect of formulation and processing conditions on the rheological and textural properties of a semi-liquid syrup model. Food Res. Int. 43, 678–682.

NPCS Board of Consultants and Engineers, 2009. Handbook on Textile Auxiliaries, Dyes and Dye Intermediates Technology. Asia Pacific Business Press Inc. Kamla Nagar, Delhi, India.

Pavithra, A.S., Chetana, R., Babylatha, R., Archana, S.N., Bhat, K.K., 2013. Studies on soft centered coated snacks. J. Food Sci. Technol. 50, 393–398.

Pongsawatmanit, R., Chantaro, P., Nishinari, K., 2013. Thermal and rheological properties of tapioca starch gels with and without xanthan gum under cold storage. J. Food Eng. 117, 333–341.

Pongsawatmanit, R., Yakard, N., Suwonsichon, T., 2011. Effect of xanthan gum on the quality of syrup thickened by modified starch during heating and storage. Kasetsart J. (Nat. Sci.) 45, 128–135.

Razavi, S.M.A., Habibi Najafi, M.B., Alaee, Z., 2007. The time independent rheological properties of low fat sesame paste/date syrup blends as a function of fat substitutes and temperature. Food Hydrocolloid 21, 198–202.

Steffe, J.F., 1996. Rheological Methods in Food Process Engineering, second ed. Freeman Press, East Lansing, MI, USA.

Taylor, R., 1990. Interpretation of the correlation coefficient: a basic review. J. Diagn. Med. Sonog. 6, 35–39.

Wang, C.S., Natale, G., Virgilio, N., Heuzey, M.C., 2016. Synergistic gelation of gelatin B with xanthan gum. Food Hydrocolloid 60, 374–383.

Wang, Z., Yang, K., Brenner, T., Kikuzaki, H., Nishinari, K., 2014. The influence of agar gel texture on sucrose release. Food Hydrocolloid 36, 196–203.

Willams, P.A., Phillips, G.O., 2009. Introduction. In: Willams, P.A., Phillips, G.O. (Eds.), Handbook of Hydrocolloids, second ed. Woodhead Publishing Limited, Cambridge, UK, pp. 1–22.

Williams, P.A., Phillips, G.O., 2003. Gums: properties of individual gums. In: Caballero, B., et al. (Eds.), Encyclopedia of Food Sciences and Nutrition, second ed. Academic Press, San Diego, CA, USA, pp. 2992–3001.