Research Article

Effects of hydrocolloids on microstructure and textural characteristics of instant noodles

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Abstract

The effects of hydrocolloids; guar gum, xanthan gum and carboxymethyl cellulose (CMC) at 0.5 and 1.0%w/w the noodle properties were investigated. The model noodle system was used to determine the effect of hydrocolloids on pasting properties by Rapid-Visco Analyzer (RVA). The result shows that the addition of guar gum and xanthan caused the increase of the peak viscosity, breakdown, final viscosity and setback of wheat flour as compared to control. After cooking the noodle, the lightness of cooked noodle with hydrocolloids was increased; while its redness and yellowness were decreased as compared to the control sample. Furthermore the ratio of cooking yield was higher in noodle with 1% guar gum or xanthan gum, and CMC (0.5, 1.0%). The SEM micrographs of cooked noodle show porous structure on its surface; while the web like structure was observed on its cross section. Moreover, the addition of 1.0% guar gum and xanthan gum had the lowest maximum stress and strain values. The alteration of texture characteristic was caused by the different microstructures when adding hydrocolloids. On the other hand, the addition of CMC with different concentrations hardly altered the texture parameters and the structure was similar to the control sample.

Keywords: guar, xanthan, carboxymethyl cellulose, RVA, wheat flour, starch, Thailand.

Introduction

Instant noodles are among the popular products due to their convenience with an acceptable mouthfeel [1]. These properties are affected by the interactions of certain ingredients including water, starch, gum and others. The major problem of dried instant noodles is the change of noodle texture during storage that led to deteriorate quality of noodles after cooking. Many researchers found that the hydrocolloids, widely used as additives in the food industry so as to improve food texture, retard starch retrogradation, improve moisture retention and enhance the overall quality of products during storage [2].

Some researchers have found that the alginate, xanthan, κ-carrageenan were able to reduce the loss of moisture content during the storage of bread and yellow layer cake [3, 4]. These researchers also

found that hydrocolloids could improve the quality of bread such as increasing the viscoelastic properties of bread dough and the specific volume [2], reducing the crumb hardness of fresh bread [5] and also increasing the overall quality of fresh bread [3]. In addition, it was found that alginate and HPMC had an anti-staling effect to retard the crumb hardening by retarding the rate of amylopectin retrogradation [3, 6]. Xanthan gum had the greatest effect to increase the batter viscosity which could slow down the rate of gas diffusion and retain gasses during the early stage of baking which gave the higher final cake volume [4, 7]. Also the microstructure of eggless cake revealed some relationship between protein matrix and HPMC as well as xanthan gum [7].

Although many researchers have studied the utilization of hydrocolloids in several food products, little study has been undertaken on the use of hydrocolloids in instant noodle products. The objective of this study was to compare the effects of selected hydrocolloids, namely guar gum, xanthan gum and carboxymethyl cellulose at 0.5 and 1% on cooking properties and textural properties of dried instant noodle.

Materials and Methods

Wheat flour with medium protein content, tapioca flour and table salt (sodium chloride) were purchased from a supermarket in Thailand. Alkaline salt was provided from Thai President Foods Public Company Ltd. Carboxymethyl celllulose (CMC), xanthan gum and guar gum were obtained from Bronson and Jacobs International Co. Ltd.

Pasting properties
The pasting property of noodle flour mix was carried out by using Rapid Visco Analyzer (RVA). The instant noodle flour mix was composed of wheat flour, tapioca flour, sodium chloride and alkaline salt (potassium carbonate: sodium carbonate; 1:1). The wheat and tapioca flour with 9:1 ratio (10% w/w dry basis) was dispersed in NaCl (1.2% w/w flour basis) and alkaline salt (0.5% w/w flour basis) solution under magnetic stirring as control. For samples with hydrocolloids (guar gum, xanthan gum and CMC), the hydrocolloids were previously hydrated in deionized water and subsequently mixed with NaCl and alkaline salt solution to obtain 0.5% w/w (flour basis) and then gradually added wheat and tapioca flour under magnetic stirring and stirred for 5 min to avoid lump formation. The samples (28 grams) were then poured into aluminium containers and stirred manually using a plastic paddles for 20-30s before insertion into the RVA machine. The heating and cooling cycles were used pre-programmed profile as follows; the slurry was held at 50°C for 1 min, heated to 95°C within 7.50 min and then held at 95°C for 5 min, cooled to 50°C and then held at 50°C for 7.50 min, while maintaining a rotation speed of 160 rpm. The pasting temperature, peak viscosity, breakdown, final viscosity and setback were recorded. All tests were performed in two replications.

Preparation of instant noodles
The instant noodles were formulated by mixing 89.67% wheat flour (9.8% protein content), 8.59% tapioca flour, 1.16% salt , 3.02% alkaline salts (the mixture of potassium carbonate and sodium carbonate on 1:1 ratio), 0.1 or 0.5% gum (flour basis) and 35-45% of water. Wheat flour was mixed with tapioca flour in the mixing bowl prior to the addition of water containing hydrated hydrocolloids, dissolved salts and alkaline salt. Then all ingredients were mixed to get crumbly dough with uniform particle sizes. After resting for 30 minutes, the noodle dough was sheeted by a noodle making machine to get the final thickness of noodle sheet (0.80 mm) before cutting. The noodle strands were then steamed for 3.30 min and dried by using a tray drier at 80°C for 45 minutes.

Cooking properties

Optimum cooking time was modified by using the Approved Method 66-50 [8]. Instant noodle samples were broken into pieces approximately 5 cm long to permit free movement in boiling water. 10 g of sample was added to a beaker containing 120 ml of boiling distilled water and timing started. Then the samples were removed at 30 second time intervals and placed into room temperature water. Five pieces of samples were squeezed between two pieces of glass. When the white centre core of 3 pieces of samples disappeared, the timer was stopped and recorded as "Optimum Cooking Time".

Cooking yield was determined according to Beta and Corke [9]. Noodle strands (15 grams) were cooked to reach the optimum cooking conditions in 180 ml boiled distilled water. Then the cooked noodle strands were placed in the water at room temperature for one minute, drained and the final weight recorded. The noodle weight after cooking was calculated for percentage of "Cooking yield".

Cooking loss was modified by using the approved method 66-50 [8]. The cooking water was transferred into the pre-weighed 600 mL-beaker and then evaporated in the hot air oven at $100 \pm 1°C$ for 20 hrs. Then the beaker was weighed until constant weight was obtained and calculated for the percentage of "Cooking loss".

Noodle colour measurement

The colour of dough sheet (the sample after sheeting process) and cooked noodle samples (the cooked instant noodle) were measured by a spectrophotometer (Minolta Spectrophotometer, model CM-3500d) equipped with a D65 illuminant using the CIE L*, a* and b* colour scale. The noodle dough sheet was folded into three layers and cooked noodle samples were placed onto the petri-dish for measurement. The samples were covered with black container to avoid the external lighting [10]. The measurements were made in triplicate at two random locations on the surface.

Noodle structure

Both the surface and cross section of cooked noodles were prepared according to Chewangkul [11] prior to observing under Scanning Electron Microscope (SEM; JSM-6480LV, JEOL, Japan). The images were obtained at an accelerating voltage of 15.0 kV at 500 and 1000 magnifications.

Textural characteristics of cooked noodles

Raw noodles (15 g) were cooked to reach the optimum cooking time and immediately rinsed with water at ambient temperature. Ten noodle strands were placed onto a petri-dish and rested to equilibrate for 10 minutes. Tensile strength of noodle was measured by using Texture Analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK) equipped with Spaghetti Tensile grips (A/SPR). Five - kg load cell was used to measure the tensile strength of cooked noodles (following the application guide of TA software). Force (g) and distance (mm) were calculated by TA software. Max stress and max strain were calculated by following Tang, *et al* [12] equation.

$$\text{Max strain} = \ln[1 + \frac{\Delta Lmax}{L}] \qquad\qquad \text{Max stress} = \frac{fmax(L + \Delta Lmax)}{\pi r2L}$$

f_{max} is the compressive force at moment of failure
L_{max} is the corresponding deformation,
R and L are the original radius and length of the gel specimen respectively.

Results and Discussion

Pasting properties of the instant noodle flour mix

The pasting properties of the instant noodle flour mix with the addition of guar gum, xanthan gum and CMC are shown in Table 1. The control sample was composed of wheat flour, tapioca flour, NaCl and alkaline salt without the addition of hydrocolloid. From Table 1, it shows that the addition of hydrocolloids affected the pasting properties of the noodle flour mix.

Table 1. Pasting properties of instant noodle flour mix with various hydrocolloids.

Condition	Pasting temp. (°C)	Viscosity (cP)			
		Peak	**Breakdown**	**Final**	**Setback**
Control	88.6b	2306.5c	1094c	2378.5c	1166b
GG 0.5%	79.12c	4094.5a	2418a	3997a	2320.5a
XG 0.5%	80.28c	3187.5b	1638b	3449b	1900a
CMC 0.5%	92.65a	2157c	674c	2305c	822b

Means in the same column followed by different letters are significantly different ($P \le 0.05$).
GG, XG and CMC stand for Guar gum, Xanthan gum and Carboxymethyl Cellulose.

The pasting properties of flour with the addition of 0.5% guar gum or xanthan gum show similar trends. Upon addition of guar and xanthan gum, it caused the decrease of pasting temperature; but led to the increase of peak, breakdown, final and setback viscosity as compared to control. On the other hand, the addition of CMC only significantly increased the pasting temperature.

The alteration of pasting properties when adding hydrocolloids may be due to the interaction between hydroxyl groups of starch and hydrocolloid [13]. From Table 1, the results suggest that the addition of either guar or xanthan gum could assist the swelling of starch granules since the pasting profile had shifted to the higher value. However, the addition of CMC might slow the swelling process since the pasting temperature increased and slightly affected the viscosity of the system.

The cooked noodles relied on the gelatinization properties of starch for their physical structure and eating quality [14]. Batey *et al* [15] found that there were significantly positive correlations between peak viscosity and breakdown of starch and flour with alkaline noodle quality by using RVA technique; the higher peak viscosity and breakdown gave the softer texture of noodle, which is required for Japanese noodles [14]. Therefore, the addition of guar gum or xanthan gum might promote the good quality for Japanese noodles, but might not be suitable for alkaline noodles which require a firm and elastic texture [16]. In order to use hydrocolloids to improve noodle quality, it is necessary to understand the effect of hydrocolloids used on the pasting properties of the noodle flour mix which could have an impact on the properties of cooked noodle.

Colour characteristics

The colour of dough sheet and cooked noodles are summarized in Table 2. The results show that the hydrocolloids only slightly affected the dough colour. Upon the addition of 1.0% hydrocolloids, the dough colour became lighter, with more redness due to the unique colour of hydrocolloids.

In general, cooked noodle colour quality requires good brightness and yellowness with no observed greenness or redness [17, 18]. The addition of hydrocolloids increased the lightness, especially with both 0.5% and 1.0% of CMC and 1.0% of xanthan gum; while the yellowness of cooked noodle, especially at 1.0% xanthan gum was decreased. This might be due to the water retention properties of the cooked noodles with xanthan gum and CMC. However, the results also show that the noodles with 0.5% and 1.0% of CMC became slightly greener, as compared to control, which might be due to the original colour of CMC.

Table 2. Colour characteristics of dough sheet and cooked noodles.

Condition	Dough sheet			Cooked noodles		
	L*	a*	b*	L*	a*	b*
Control	76.21bc	0.16b	20.86a	65.30d	-0.41a	22.68a
GG 0.5%	76.46b	0.38b	20.02abc	65.64d	-0.48a	22.29a
GG 1.0%	74.71d	0.76a	19.95bc	66.55c	-0.58ab	20.15c
XG 0.5%	77.73a	0.38b	19.30c	68.09b	-0.70ab	20.39bc
XG 1.0%	75.48bcd	0.80a	19.76c	69.07a	-0.90abc	18.83d
CMC0.5%	77.62a	0.33b	19.50c	68.83ab	-1.41c	21.14b
CMC1.0%	75.23cd	0.69a	20.75ab	68.90ab	-1.08bc	20.98bc

Means in the same column followed by different letters are significantly different (P ≤ 0.05)
     L* (Lightness) the positive value means white and negative value means black
     a* (Redness) the positive value means redness and negative value means greenness
     b* (Yellowness) the positive value means yellowness and negative value means blueness

Cooking properties
The optimum cooking time, cooking yield and cooking loss of noodles are shown in Table 3. Regarding the optimum cooking time, the addition of guar gum at both concentrations and xanthan gum at 1.0% had the longest optimum cooking time; while using CMC at 1.0% had the shortest cooking time. The cooking yield increased with the increasing hydrocolloid concentration. The hydrocolloid types used in this experiment slightly affected the cooking yield. It is also presented that the cooking loss of almost all cooked noodles was not significantly different except the 1% xanthan gum, which had the highest cooking loss.

Table 3. Effect of different hydrocolloids on OCT, cooking yield and cooking loss of instant cooked noodles.

Conditions	OCT (minutes)	Cooking yield (ratio)	Cooking loss (%)
Control	4.00	3.36e ± 0.04	8.74b ± 0.30
GG 0.5%	4.30	3.38de ± 0.05	7.85b ± 0.30
GG 1.0%	4.30	3.65ab ± 0.10	8.82b ± 0.26
XG 0.5%	3.45	3.47de ± 0.05	8.16b ± 0.26
XG 1.0%	4.30	3.71a ± 0.03	10.37a ± 1.71
CMC 0.5%	3.45	3.49cd ± 0.05	8.93b ± 0.21
CMC 1.0%	3.30	3.58bc ± 0.06	8.51b ± 0.19

Means in the same column followed by different letters are significantly different (P ≤ 0.05)

Addition of hydrocolloids increasing the cooking yield or water absorption properties of noodle samples might be due to the water binding and holding properties of hydrocolloids, which could be more pronounced when the concentration increased. In addition, the result from RVA shows the ability of hydrocolloids to promote the swelling of starch granules, causing the higher cooking yield ratio. However, the cooking loss value related to the structural strength of noodle, the lower this value, the higher structural strength. From this experiment, the noodle with 1.0% xanthan gum had the highest cooking loss, which might lead to the weaker noodle structure than others.

Noodle structure
The SEM results of cooked noodles are shown in Figure 1. The surface structure of control sample had many pores with various sizes connected together like a network on its surface structure. On its cross section view, it shows the irregular sizes of thick network. In the presence of 0.5% guar gum (Figure 1i), the noodle surface network seemed to be thinner with many pores when compared to control. When the concentration increased to 1.0% (Figure 1j), the network appeared disrupted since there were more open network structures. From Figure 1 (j and l), the micrographs showed that, as the hydrocolloid concentration increased, there were more open pores and a thicker continuous network. This occurrence might be due to the phase separation between hydrocolloid and starch

materials when cooked since the hydrocolloid could not thoroughly disperse at high concentration. On the other hand, the structure of cooked noodles with CMC appeared similar to the control but with thick network connection. Both surface and cross-sectioned view of cooked noodles, it showed the difference structure, which could affect the textural characteristics of noodles.

Figure 1. Micrographs of both cooked noodle surfaces (500x) (a-g) and cross-section (1000x) (h-n).

control (a,h), with 0.5% guar gum (b,i), with1% guar gum (c,j), with 0.5% xanthan gum (d,k), with 1% xanthan gum (e,l), with 0.5% CMC (f,m) and with 1% CMC (g,n)

The cross-sectioned images of cooked noodles show the differences among the samples. The structure of control sample was very dense and had small pore size; while the structure of cooked noodles with 0.5% guar gum and xanthan gum appeared looser and had more open areas. However, with the addition of 1.0% guar gum and xanthan gum, the micrographs showed non-homogenous noodle structure. These indicated that hydrocolloids might affect the textural properties of cooked noodle.

Textural characteristics of cooked noodles
The addition of hydrocolloids had different effects on noodle texture parameters as shown in Table 4.

Table 4. Texture characteristics of instant cooked noodles with and without hydrocolloids.

Condition	Max strain	Max stress (kPa)
Control	0.39b ± 0.13	50.92b ± 11.32
GG 0.5%	0.49a ± 0.18	65.32a ± 21.16
GG 1.0%	0.29c ± 0.14	36.61c ± 8.73
XG 0.5%	0.39b ± 0.12	51.01b ± 12.30
XG 1.0%	0.29c ± 0.15	41.57c ± 12.26
CMC 0.5%	0.52a ± 0.15	65.40a ± 14.84
CMC 1.0%	0.41b ± 0.18	49.51b ± 14.73

Values were the average from 10 strands of three replicates from different instant noodle samples per batch; different letters in the same column indicate significant differences. ($P \leq 0.05$)

The addition of 0.5% hydrocolloids increased the maximum stress and strain values of cooked noodles when compared to the 1.0% concentration. The results show that the addition of 0.5% hydrocolloids could promote the strength of noodles by increasing the maximum stress and strain. The increase of noodle strength when adding the 0.5% guar gum and CMC was caused by the interaction between the hydrocolloids with the gluten network and yielded the higher maximum stress, especially CMC, which has the ability to form a film with gluten in the structure [19]. On the other hand, at the higher hydrocolloid concentration (1%), the high molecular weight hydrocolloid might interfere the gluten network formation [20], causing the decrease of hardness and elasticity of noodles. Furthermore, from Figure 1, the micrographs indicated that the addition of hydrocolloids especially at 1.0% gave a non-homogenous and porous structure. However, the hydrocolloid types, different molecular structure, could also affect the textural properties of instant noodles differently and this needs further investigation.

Acknowledgements

References

1.   Hatcher, D.W., Kruger, J.E. and Anderson, M.J. (1999). Influence of water absorption on the processing and quality of oriental noodles. *Cereal Chemistry.* 76(4), 566-572.

2.   Rosell, C.M., Rojas, J.A. and Benedito de Barber, C. (2001). Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocolloids.* 15(1), 75-81.

3.   Guarda, A., Rosell, C.M., Benedito, C. and Galotto, M.J. (2004). Different hydrocolloids as bread improvers and anti-staling agents. *Food Hydrocolloids.* 18(2), 241-247.

4.   Gómez, M., Ronda, F., Caballero, P.A., Blanco, C.A. and Rosell, C.M. (2007). Functionality of different hydrocolloids on the quality and shelf-life of yellow layer cakes. *Food Hydrocolloids.* 21(2), 167-173.

5.   Davidou, S., Meste, M.L., Debever, E. and Bekaert, D. (1996). A contribution to the study of staling of white bread: effect of water and hydrocolloid. *Food Hydrocolloids.* 10(4), 375-383.

6.   Barcenas, M.E. and Rosell, C.M. (2005). Effect of HPMC addition on the microstructure, quality and aging of wheat bread. *Food Hydrocolloids.* 19(6), 1037-1043.

7.   Ashwini, A., Jyotsna, R. and Indrani, D. (2009). Effect of hydrocolloids and emulsifiers on the rheological, microstructural and quality characteristics of eggless cake. *Food Hydrocolloids.* 23(3), 700-707.

8.   AACC (2000). Approved Methods of the American Association of Cereal Chemists. 10th ed. American Association of Cereal Chemists, St. Paul, Minnesota.

9.   Beta, T. and Corke, H. (2001). Noodle quality as related to sorghum starch properties. *Cereal Chemistry.* 78(4), 417-420.

10.   Hatcher, D.W., Lagasse, S.S., Dexter, J.E., Rossnagel, B. and Izydorczyk, M. (2005). Quality characteristics of yellow alkaline noodles enriched with hull-less barley flour. *Cereal Chemistry.* 82(1)*,* 60-69.

11.   Chewangkul, L. (2002). Wheat Based Instant Noodle: Microstructure and Related Properties. (PhD dissertation), Thailand: Kasetsart Univ.141 p.

12.   Tang, J., Lelievre, J., Tang, M.A. and Zeng, Y. (1994). Polymer and ion concentration effects on gel strength and strain. *Journal of Food Science,* 59(1), 216-220.

13.   Christianson, D.D., Hodge, J.E., Osborne, D. and Detroy, R.W. (1981). Gelatinization of wheat starch as modified by xanthan gum, guar gum, and cellulose gum. *Cereal Chemistry.* 58(6), 513-517.

14.   Miskelly, D.M. (1996). Pasta and noodle technology. St. Paul, MN: American Association of Cereal Chemists. 356p.

15.   Batey, I.L., Curtin, B.M. and Moore, S.A. (1997). Optimization of Rapid-Visco Analyzer test conditions for predicting Asian noodle quality. *Cereal Chemistry*. 74(4)*,* 497-501.

16.   Fu, B.X. (2008). Asian noodles: History, classification, raw materials and processing. *Food Research International,* 41(9), 888-902.

17.   Hou, G. and Kruk, M. (1998). Asian noodle technology. Technical Bulletin. 20(12), 1-10.

18.   Charles, A.L., Huang, T.C., Laia, P.Y., Chenc, C.C., Leed, P.P. and Chang, Y.H. (2007). Study of wheat flour–cassava starch composite mix and the function of cassava mucilage in Chinese noodles. *Food Hydrocolloids.* 21(3), 368-378.

19.   Choy, A.I., May, B.K. and Small, D.M. (2012). The effects of acetylated potato starch and sodium carboxymethyl cellulose on the quality of instant fried noodles. *Food Hydrocolloids.* 26(1), 2-8.

20.   Linlaud, N., Ferrer, E., Puppo, M.C. and Ferrero, C. (2011). Hydrocolloid interaction with water, protein and starch in wheat dough. *Journal of Agricultural Chemistry,* 59(2), 713-719.