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# Effects of gums on physical properties, microstructure and starch digestibility of dried-natural fermented rice noodles

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ABSTRACT

The effects of gums including carboxymethyl cellulose (CMC), xanthan gum (XG) and guar gum (GG) on physical properties, microstructure and starch digestibility of dried-natural fermented rice noodles were investigated. The gums, each at 0.05 and 0.10 g/100 g wet basis, were added to the flour during rice noodle production. Control was the sample without the addition of gums. Physical properties (color, water absorption, cooking loss and firmness), microstructure, starch composition and in vitro starch digestibility were determined. Generally, the addition of gums improved the physical qualities of rehydrated fermented rice noodles as evidenced by high water absorption and low cooking loss. CMC provided the best result for improvement of the physical properties of rice noodles. The addition of gums promoted the porous microstructure in rice noodles. In terms of starch digestibility, the addition of gums increased the rate of starch digestion and consequently provided high estimated glycemic index (GI). Samples with XG showed the highest starch digestion rate and estimated GI values when compared with CMC and GG. It is concluded that CMC, XG and GG improved the texture and cooking quality of dried-natural fermented rice noodles but they had negative effects on starch digestion rate and estimated GI.

## 1. Introduction

Rice has been widely used as a primary gluten-free flour base for scientific and industrial purposes. However, there is still a challenge to formulate gluten-free products with rice because rice flour does not have the functionality of structural protein called gluten. It has been recognized that rice dough has low elastic property, weak resistance to stretch, and poor mixing tolerance [1].

Natural fermented rice noodles are popular in many Asian countries. They can be called differently such as sour *Mifen* in China, *Khanom Jeen* in Thailand, *Mohingar* in Myanmar, *Khao Pen* in Laos and *Banh Da* in Vietnam, etc. For most rice noodle factories, fermentation is conducted in large parallelepiped steel tanks at ambient temperature. Tanks are almost completely filled with polished rice grains and covered with a thin layer (8–15 cm) of water. The rice grains are statically fermented naturally, without a starter, for a few days, then wet-milled, steamed, and extruded into rice noodles [2]. Natural fermentation has been reported as a traditional process to improve the textures and enhance sensory properties of rice noodles [3–5]. Lactic acid is the dominant organic acid produced by fermentation. The fermentation of raw milled rice decreased protein and lipid content, increased the purity of rice starch, and thus improved the texture of fermented rice noodles. However, the low molecule weight sugars produced during fermentation weakened the noodle texture [2].

In addition, due to the absence of gluten, freshly-produced fermented rice noodles show relatively poorer cohesive and extensible textural properties when compared to wheat-based noodles. It also contains considerably high amount of water. Therefore, the shelf life of natural fermented rice noodles is very short (a few days). Drying by various techniques is employed to produce dried rice noodles with enhanced shelf life. Dried rice noodles can be reconstituted by boiling in hot water. However, water removal during drying processes severely affects the textural structure of dried rice noodles. It also affects the properties of rehydrated rice noodles.

Several trials have been made to improve the rice noodle properties. The addition of hydrocolloids, such as natural gums, has often been suggested as a potential way to overcome the processing difficulty and functionality of rice starch. Natural and modified hydrocolloids are widely used in noodles and their effects depend on the types and amounts of gum added [6]. The gums in food system can be used to mimic the viscoelastic properties of gluten, thereby leading to improved structure, mouth feel, and acceptability in foods [7]. Guar gum (GG), xanthan gum (XG), locust bean

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**Table 1**
Textural properties of the rehydrated fermented rice noodles as investigated by color, water absorption, cooking loss and firmness values.

| Samples | Color-L* | Color-a* | Color-b* | Water absorption (g/100 g wet basis) | Cooking loss (g/100 g wet basis) | Firmness (g.force) |
|---|---|---|---|---|---|---|
| Control | 68.33 ± 0.40d | −0.43 ± 0.06a | 4.10 ± 0.10d | 194.75 ± 6.12a | 1.06 ± 0.03a | 44.01 ± 0.43c |
| CMC005 | 71.73 ± 0.12b | −0.77 ± 0.06c | 3.67 ± 0.12e | 231.08 ± 6.85b | 0.82 ± 0.06c | 47.21 ± 1.06b |
| CMC010 | 69.90 ± 0.35c | −0.67 ± 0.06c | 3.23 ± 0.15f | 257.17 ± 3.00a | 0.81 ± 0.05c | 45.36 ± 0.41bc |
| XG005 | 67.43 ± 0.25e | −0.53 ± 0.05ab | 5.17 ± 0.25b | 198.88 ± 6.97d | 0.93 ± 0.19bc | 43.63 ± 0.90c |
| XG010 | 68.77 ± 0.40d | −0.63 ± 0.07bc | 4.50 ± 0.10c | 210.83 ± 3.49c | 1.13 ± 0.06a | 45.05 ± 1.27c |
| GG005 | 71.80 ± 0.26b | −0.73 ± 0.12c | 5.80 ± 0.26a | 204.32 ± 2.61 cd | 0.91 ± 0.04bc | 49.19 ± 1.60a |
| GG010 | 72.47 ± 0.21a | −0.50 ± 0.10ab | 5.60 ± 0.20a | 210.77 ± 7.15c | 0.98 ± 0.08abc | 49.43 ± 1.32a |

*Note*: CMC = carboxymethyl cellulose, XG = xanthan gum, GG = guar gum; 005 = 0.05 g/100 g, 010 = 0.10 g/100 g (wet basis) addition.

gum (LBG), alginates, and carboxymethyl cellulose (CMC) are common stabilizers used in food industry to provide viscosity, improve firmness, and give body and mouth feel to the end product [6,8]. These are probably due to the effects of gums on gelatinization and retrogradation of starch food systems. It has been reported that non-ionic polysaccharides, including GG, LBG and konjac glucomannan, interacted with amylopectin upon heating, leading to increase in paste viscosity. Gums could also increase the effective concentration of amylose and amylose-like component in the continuous phase through their thermal thickening, leading to acceleration of short-term retrogradation. However, they should depress gel properties and inhibit the crystallization of amylose and/or the co-crystallization between amylose and amylopectin, leading to retardation of long-term retrogradation [9].

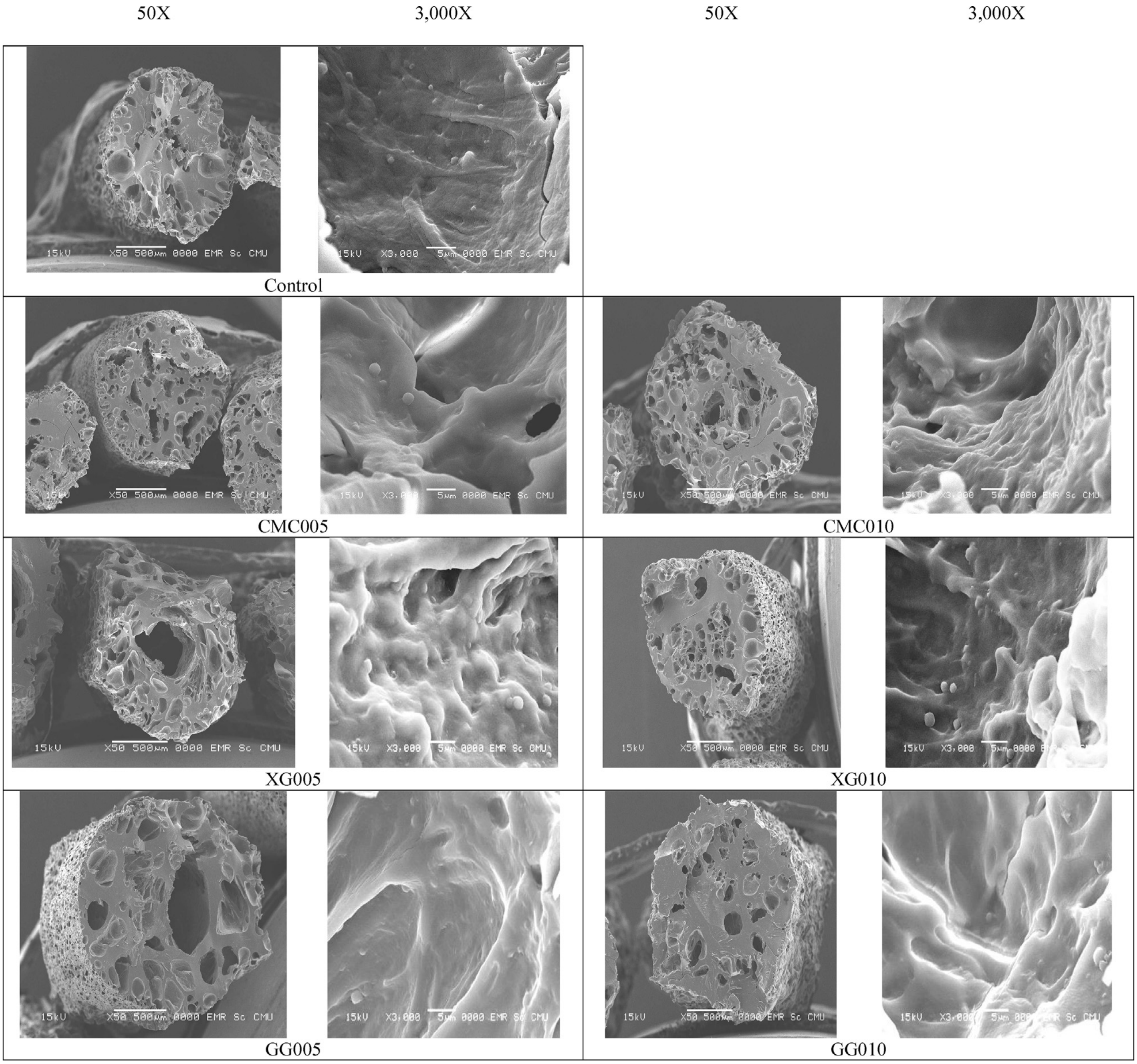

**Fig. 1.** SEM images of the dried-natural fermented rice noodles (CMC = carboxymethyl cellulose, XG = xanthan gum, GG = guar gum; 005 = 0.05 g/100 g, 010 = 0.10 g/100 g (wet basis) addition).

**Table 2**
Starch composition (RS = resistant starch, Non-RS = non-resistant starch, TS = total starch) of the dried-natural fermented rice noodles.

| Samples | RS (g/100 g dry basis) | Non-RS (g/100 g dry basis) | TS (g/100 g dry basis) |
|---|---|---|---|
| Control | 1.29 ± 0.20a | 88.90 ± 2.78a | 90.18 ± 2.97a |
| CMC005 | 1.04 ± 0.03b | 72.93 ± 2.47b | 73.97 ± 2.45b |
| CMC010 | 0.97 ± 0.04b | 76.43 ± 3.86b | 77.40 ± 3.82b |
| XG005 | 1.29 ± 0.08a | 72.31 ± 2.71b | 73.60 ± 2.79b |
| XG010 | 1.17 ± 0.08ab | 72.07 ± 2.55b | 73.23 ± 2.47b |
| GG005 | 1.09 ± 0.03ab | 73.44 ± 0.91b | 74.53 ± 0.93b |
| GG010 | 1.06 ± 0.11ab | 75.48 ± 2.64b | 76.54 ± 2.75b |

*Note*: CMC = carboxymethyl cellulose, XG = xanthan gum, GG = guar gum; 005 = 0.05 g/100 g, 010 = 0.10 g/100 g (wet basis) addition.

Moreover, the interactions between starch and gums have a nutritional impact on food products. The potential for altering starch digestibility by blending gums has been a focus in current research studies [10], as gums can modify food structure, texture, and viscosity, resulting in altered accessibility of enzymes to starch granules and processed starch materials [11]. However, no clear trend on the effects of various gums on starch digestibility could be established. They were largely dependent on several factors such as the gum types, starch origins and food types [12,13]. In views of the importance of gums being used widely as food ingredients and increasing demand of rice noodles as non-gluten foods, the objective of this study was to investigate the effects of three different gums (CMC, XG and GG) on physical properties, microstructure and starch digestibility of dried-natural fermented rice noodles. The information obtained could be useful for rice noodle researchers and manufacturers.

## 2. Materials and methods

### 2.1. Materials

Polished and aged rice with amylose content of 30.45 g/100 g dry solid was obtained from Phitsanulok province, Thailand. CMC, XG and GG were obtained from Chemipan Co., Ltd. (Thailand). All chemicals and enzymes were analytical grade purchased from Sigma-Aldrich (Thailand) Co., Ltd.

### 2.2. Fermented rice noodle preparation

Fermented rice noodles were prepared as described earlier [5] with some modifications. Polished rice (2 kg) was naturally fermented for 72 h in a stainless steel bucket filled with tap water (1 cm above the surface of the rice). Fresh tap water was replaced daily to avoid spoilage. The fermented rice was then wet milled and the slurry was left in the bucket for 12 h for sedimentation. The sediment flour was put into a filter bag and excess water was eliminated by pressing. The drained wet flour was mixed with the additives (if any), kneaded, pregelatinized by steaming for 30 min and kneaded again to paste-like consistency. To make the noodles, the flour was extruded into boiling water pan and boiled for 5 min. The rice noodles were taken from boiling water pan and put into cold water. Cooled rice noodles were dried at 60 °C using the horizontal hot air dehydrator (STX Dehydra Model 1200W-XLS, USA) until the moisture content reached about 13 g/100 g wet basis.

For the addition of the gums, CMC, XG and GG (each at 0.05 and 0.10 g/100 g wet basis) were added to the flour after sedimentation (before pre-gelatinization). The latter processes were the same as described above. These provided seven samples for investigation (control, CMC005, CMC010, XG005, XG010, GG005 and GG010) when 050 = 0.05 g/100 g and 010 = 0.10 g/100 g (wet basis). Control was the sample without the addition of any gum.

### 2.3. Physical properties

Physical properties of the rehydrated rice noodles were evaluated based on several parameters including color, cooking loss, water absorption and firmness.

The color after rehydration was determined using a colorimeter (Minolta, CR-10, Japan) in CIE L*a*b* system.

Cooking loss and water absorption of noodle samples were determined according to the standard AACC method as described previously [14]. 5 g of dried rice noodle was boiled in 150 mL boiling water for 4 min (no white core at the center of the cooked noodles), drained for 5 min, and then weighed. Cooking water was evaporated and dried at 105 °C to a constant weight. Cooking loss was expressed as a percentage of dry matter lost during cooking to dry sample weight. The water absorption was the percentage of weight increase in cooked rice noodles compared to dried samples.

Firmness of rehydrated rice noodles was measured immediately by a Texture Analyzer (TA-XT2, Stable Micro Systems, England) following the method described elsewhere [15] with some modifications. Five strands of noodles were laid on the platform securely lined with filter paper fastened by double-sided adhesive tape. The thickness of the noodle was measured, and it was subjected to 75% deformation in compression mode at a probe speed of 1.00 mm/sec, using a Perspex knife blade. The maximum force (g) to compress the noodle was noted as firmness.

### 2.4. Microstructure

Microstructure of dried rice noodles were examined by SEM (JEOL JSM-5910LV, JOEL USA Inc.). Samples were cut in cross-section and separately placed on the sample holder with the help of a double sided scotch tape and sputter-coated with gold (2 min, 2 mbar) before transferred to the microscope.

### 2.5. In vitro starch digestion and modeling of starch digestograms

Starch composition including resistant starch (RS), non-RS and total starch (TS) content of the dried rice noodles was determined enzymatically using the Megazyme assay kit (Megazyme International Ireland) as described elsewhere [16].

The time-course starch digestion in the dried rice noodles was determined using a rapid in vitro digestibility assay based on glucometry [17]. About 0.5 g of ground sample, to pass 100 mesh screen, was weighted and mixed with distilled water (1:1.5 w/w) and boiled at 100 °C for 20 min to obtain the gelatinized samples. The samples were then treated with artificial saliva containing porcine $\alpha$-amylase (Sigma A3176 Type VI-B) before pepsin (Sigma P6887; pH 2.0) was added and incubated at 37 °C for 30 min in a water bath operating under continuous shaking. The digesta was neutralized with NaOH before adjusting the pH to 6.0 (sodium acetate buffer) prior to the addition of pancreatin (Sigma P1750) and amyloglucosidase (Megazyme E-AMGDF). The mixture was incubated for 4 h, during which the glucose concentration in the digesta was measured with an Accu-Check® Performa® glucome-

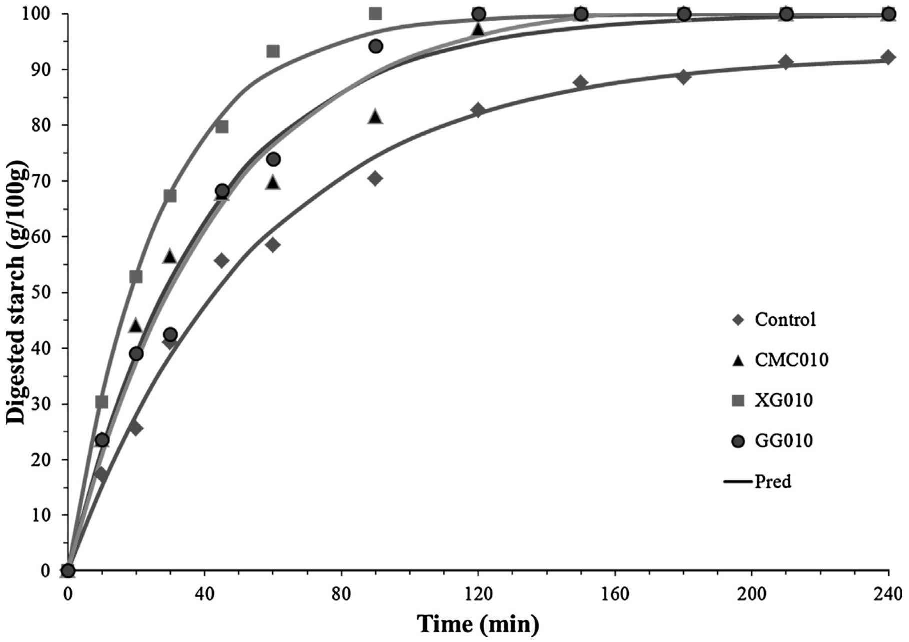

**Fig. 2.** Starch digestograms of the dried-natural fermented rice noodles (CMC = carboxymethyl cellulose, XG = xanthan gum, GG = guar gum; 005 = 0.05 g/100 g, 010 = 0.10 g/100 g (wet basis) addition).

ter (Roche Thailand Ltd., Bangkok, Thailand) at specific periods (0, 30, 60, 90, 120, 150, 180, 210 and 240 min). Digested starch per 100 g dry starch (DS) was calculated as in Eq. (1).

$$DS = \frac{0.9 \times G_G \times 180 \times V}{W \times S[100 - M]} \tag{1}$$

where $G_G$ = glucometer reading (mM/L), V = volume of digesta (mL), 180 = molecular weight of glucose, W = weight of sample (g), S = starch content of sample (g/100 g sample), M = moisture content of a sample (g/100 g sample), and 0.9 = stoichiometric constant for starch from glucose contents.

The digestogram (digested starch at a specific time period) of each sample was modeled using a modified first-order kinetic model, Eq. (2), as described before [18].

$$D_t = D_0 + D_{\infty-0}(1 - \exp[-Kt]) \tag{2}$$

where $D_t$ (g/100 g dry starch) is the digested starch at time t, $D_0$ is the digested starch at time t = 0, $D_\infty$ is the digestion at infinite time ($D_0 + D_{\infty\text{-}o}$), $K$ is the apparent rate constant (min$^{-1}$). $D_{\infty\text{-}0}$ was estimated from $t$ = 0–240 min.

The Microsoft Excel Solver® was used to compute the parameters of the model by minimising the sum of squares of residuals (SUMSQ) and constraining $D_\infty \leq 100$ g per 100 g dry starch, and $D_0 \geq 0$ g per 100 g dry starch. In addition to the coefficient of determination ($r^2$), the predictive ability of the models was assessed with the mean relative deviation modulus (MRDM) as described elsewhere [18].

In order to calculate the estimated GIs of the samples, the areas under the digestograms ($AUC_{exp}$) were computed with Eq. (3):

$$AUC_{\exp} = \left[D_\infty t + \frac{D_{\infty-0}}{K}\exp(-Kt)\right]_{t_1}^{t_2} \tag{3}$$

The hydrolysis index (HI) and starch digestion of each sample were calculated by dividing the area under its digestogram by the area under the digestogram of a fresh white bread which was calculated to be about 23,000 min g/100 g dry starch [19]. The hydrolysis index at 90 min ($H_{90}$) was also calculated using the same method as HI. Estimated GIs of the samples were also calculated by Eq. (4):

$$GI = \left[\frac{((39.21 + 0.803H_{90}) + (39.51 + 0.803\,\mathrm{HI}))}{2}\right] \tag{4}$$

### 2.6. Statistical analysis

Analysis of variance (ANOVA) and test of significance were performed using Minitab® ver. 17 with confidence level of 95%. The samples were randomized for all the analyses described above.

## 3. Results and discussions

### 3.1. Physical properties

Physical parameters including color, cooking loss, water absorption and firmness are shown in Table 1.

In general, physical properties of the rehydrated fermented rice noodles were affected by the addition of the gums. The changes in physical properties depended on each type of gum. Color of the noodles with added gums was found to be brighter than that of control sample as evidenced by the higher L* values. Gums tended to make the noodle color shifted towards greenness and yellowness as indicated by negative a* and positive b* values, except in CMC samples of which the yellowish color was less than the control. This may be the interferences from the color of the gum itself. Although, color may not relate to the safety of rice noodles but the white and bright colors are preferred physical qualities by consumers.

It is noticeable that the addition of gums improved water absorption and reduced cooking loss. Noodles with the addition of gums had significantly higher water absorption and lower cooking loss. In this study, CMC was found to be the best when compared to XG and GG as it gave high water absorption and low cooking loss (refers Table 1). Water absorption of the rice noodles with additives is significantly higher than that of the control sample, indicating that gums enhanced the rehydration of the rice noodle. This should also help in dried fermented rice noodles when they are subject to cooking. The quick cooking rice noodles are preferred by consumers. CMC at 0.10 g/100 g wet basis provided the maximum

**Table 3**
Model parameters, hydrolysis index (HI) and estimated glycaemic index (GI) of the dried-natural fermented rice noodles.

| Samples | $D_\infty$ (g/100 g dry starch) | K x10$^{-2}$ (min$^{-1}$) | HI | GI |
|---|---|---|---|---|
| Control | 92.87 ± 0.11c | 1.81 ± 0.01e | 74.90 ± 0.27d | 90.67 ± 0.20d |
| CMC005 | 100 ± 0.00b | 2.67 ± 0.03c | 88.26 ± 0.02b | 101.07 ± 0.06b |
| CMC010 | 100 ± 0.00b | 2.53 ± 0.08 cd | 87.57 ± 1.11bc | 100.42 ± 0.76bc |
| XG005 | 100 ± 0.00b | 3.44 ± 0.02b | 91.73 ± 0.04a | 103.84 ± 0.04a |
| XG010 | 100 ± 0.00b | 3.86 ± 0.10a | 93.09 ± 0.30a | 104.80 ± 0.20a |
| GG005 | 99.63 ± 0.51b | 2.37 ± 0.13 cd | 85.74 ± 0.58c | 99.05 ± 0.56c |
| GG010 | 102.5 ± 0.42a | 2.30 ± 0.05d | 87.80 ± 0.21b | 100.39 ± 0.19bc |

*Note*: CMC = carboxymethyl cellulose, XG = xanthan gum, GG = guar gum; 005 = 0.05 g/100 g, 010 = 0.10 g/100 g (wet basis) addition.

water rehydration and lowest cooking loss, representing 257.17 and 0.81 g/100 g wet basis respectively. The addition of gums that increased water absorption in rice noodles could rely on the ability of gums to bind water. Gums could interact with amylopectin at long exterior chains (amylose-like component), leading to the increase of viscosity (water take up) during heating [9]. Hydrocolloids including various gums have been widely used in food products to modify texture, improve moisture retention, control water mobility and maintain overall product quality during storage [20]. Nevertheless, the properties of the hydrocolloids vary in a great extent depending on their origin and chemical structure [21]. Gums provide viscosity and texture, improve firmness, give body and mouthfeel to the end product [6]. Through their ability to bind water, gums can also increase the rehydration rate of the rice product upon cooking or soaking [22]. Moreover, gum and starch interactions are also dependent on starch origin because of differences in granule size and crystalline microstructure [23].

In addition, the firmness of rice noodles with the addition of gums could also be improved. Although, this effect was not as obvious as observed in water absorption and cooking loss. Among all the gums used, the firmness of rice noodles with GG is higher than that of CMC and XG respectively (refers Table 1). As gums interacted with starch components (amylose and amylopectin), induced changes in the properties of starch/gum composite, depending on the origin and structure of the gums. We assumed that GG could form the firmer texture when compared to CMC and XG. Although, their microstructures were found to be quite different (describe next). In this study, CMC and XG did not provide satisfactory results in terms of the firmness. Especially in XG, the firmness of the noodles was not statistically different ($p > 0.05$) from the control. Rice protein contains no gluten to make a cohesive dough structure. Therefore, it has been recognized that rice dough has low elastic property, weak resistance to stretch, and poor mixing tolerance, negatively contributing to the formation of a cohesive and viscoelastic dough structure [24]. The addition of gums could enhance the cohesive and viscoelastic structure of the fermented rice noodles. Moreover, apart from the improvement of texture by the addition of gums, pregelatinization which is a process step in making rice noodles also contributes to the improved texture. Although this aspect is not the scope covered by this paper, however, it has been reported that pregelatinization of rice at partial gelatinization level provided better cooking and sensory properties in rice noodles [25].

### 3.2. Microstructure

For microstructure, the SEM images of the rice noodles, both control and samples with the additives, are shown in Fig. 1.

The high resolution SEM images revealed that gums were embedded in gelatinized starch and formed different network depending on the gum types. From Fig. 1, clear differences were observed in the microstructure of rice noodles with or without the addition of the gums. It can be seen that the addition of the gums promoted the porous structure in all samples when compared to the control sample. It is obvious that the control sample has the denser microstructure than samples with added gums. Comparing among all three studied gums, CMC provided the evenly distributed air cells with similar pore sizes. However, XG and GG gave the big pore sizes but not evenly distributed. Evenly distributed air cells in noodles added with CMC could improve the qualities of rice noodles leading to its high water absorption and low cooking loss as shown earlier. The effects of gums on starch properties were greatly dependent on the gum structure and concentration, as well as the origin of starch. Microstructures of rice starch gel with glucomannan were reported to show densely aggregated swollen starch granules while those in gels with konjac glucomannan were more evenly distributed [26]. It has been reported that starch–gum blends exhibited a phase-separated microstructure in which amylose and amylopectin rich domains were dispersed in a hydrocolloid-rich continuous phase. In the absence of hydrocolloids, starch formed micellar networks through the association of segments of amylose or amylopectin molecules, which control the swelling process during heating. When hydrocolloids are mixed with starch, leached amylose and low molecular weight amylopectins can interact with hydrocolloids during gelatinization and form different network structures that result in altered rheological properties depending on the hydrocolloid and its concentration [27,28].

### 3.3. Starch digestibility

#### 3.3.1. Starch composition

Table 2 shows the starch composition of the rice noodle samples. RS of rice noodles was found to be considerably low, ranging from 0.97–1.29 g/100 g dry basis. The results were in agreement with previously reported [16]. Control sample contained very high amount of TS (90.18 g/100 g dry basis) and it decreased when the additives were added because the addition of gums replaced starch in the sample.

Rice noodle is usually made of high amylose rice as this promotes better noodle texture [29]. Its processing also applies steaming of rice flour slurry and tempering of steamed rice sheets. These may increase RS or slowly-digestible starch portion and consequently lower the GI by means of hydrothermal treatment [30] and starch retrogradation [31]. It has been reported that high RS ingredients produced noodles that showed lower glycemic responses [32].

#### 3.3.2. In vitro starch digestibility

The digestograms of rice noodles showing percentages of digested starch versus time are shown in Fig. 2. Notably, only samples with the addition of 0.10 g/100 g are shown in the figure for clear illustration. Furthermore, Table 3 shows the starch digestibility parameters and estimated GIs of the rice noodle samples. The modified first-order kinetic model proved suitable in describing the digestograms ($r^2 = 0.986–0.998$). In general, the addition of gums to rice noodles enhanced the rate of starch digestion and consequently increased GI values. Samples with the addition of XG showed the highest starch digestion rate and estimated GI values when compared with CMC and GG added samples. The addition of CMC and GG provided similar effects. The effects of gums and other hydrocolloids on starch digestibility have been studied mostly in starch and gum mixtures. Current published papers suggested different results.

The effects of various hydrocolloids on digestibility of cooked rice were investigated [12], observing that the enzymatic digestion pattern changed in the presence of hydrocolloids. However, no clear trend could be established because the global effect on the starch digestion fractions was largely dependent on the hydrocolloid type. Even the GI trend varied greatly with the hydrocolloid type. The impact of gums and various hydrocolloids on starch hydrolysis also varied depending on the starch origin and food type [13]. It has been reported that the addition of various gums and hydrocolloids at the concentration of 5–15 g/100 g dry sample in rice starches had little or no impact on improving starch digestibility properties as determined by the in vitro method [10]. The effects of addition levels (0%, 2%, 4%) of GG, sodium alginate, XG on the retardation of in vitro starch digestibility were investigated in noodles made by various cereal flours (wheat, whole wheat, buckwheat). The estimated GI of noodles made by wheat or whole wheat flour was significantly decreased. However, the estimated GI of buckwheat flour-based noodles with hydrocolloids was slightly increased [13].

The mechanism has been proposed that hydrocolloids affected the in vitro hydrolysis of starch, changing the pattern of the starch fractions favoring the starch hydrolysis and increasing the RDS fraction. Hydrocolloids induced a shift from slow digestible starch to rapid digestible starch and therefore accelerated the enzymatic hydrolysis rate in the early stage [33]. It might also increase the hydration of flours or noodles and thereby accelerating the accessibility of digestive enzymes into starch granules and increasing the overall rate of starch hydrolysis [13].

In view of the popularity of hydrocolloids being used as food additives in starch based foods, there is less information on the comparison of starch digestive behavior by flour source, starch origin, and hydrocolloid type and level in a real food model [13]. In this study, all studied hydrocolloids accelerated the starch digestion rate and consequently increased the estimated GI values of the hydrocolloid added noodles. We assumed that the rapid starch digestion was due to the microstructure of the rice noodles. As discussed earlier, noodles without the addition of gums exhibited denser microstructure than those with added gums. Denser microstructure might restrict the transfer of the enzymes to the granules and also change the starch granule swelling pattern during gelatinization and ultimately enzyme action during starch hydrolysis. In contrast, hydrocolloid added rice noodles showed air cells which could lead to high water absorption and accelerating the accessibility of digestive enzymes into starch granules and increasing the rate of starch digestion.

## 4. Conclusion

Hydrocolloids are largely used in food processing because of their functional properties. In this study, CMC, XG and GG were added to natural fermented rice noodles in order to improve their textural properties. When applied, the texture of rice noodles as evidenced by several parameters such as water absorption, cooking loss and firmness were improved. For microstructure, SME images revealed that the gums promoted the porous structure in all samples. CMC provided the evenly distributed air cells with similar pore sizes and thereby exhibited the best results for textural improvement of the rice noodles. This study found that the addition of all tested gums increased starch digestion rate and consequently provided higher estimated GI values. It is concluded that addition of CMC, XG and GG improves the textures of dried-natural fermented rice noodles but accelerates the starch digestion rate and increase estimated GI values. Special concerns should be made for industrial applications.

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