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ORIGINAL ARTICLE

Effect of Konjac and Gellan Gum Coatings on Broth Flavor Adsorption, Textural and Sensory Properties of Rice Noodles

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ABSTRACT

The aim of this work was to investigate the impact of konjac gum (KG) and gellan gum (GG) as coating agents to enhance flavor adsorption by cooked fresh rice noodles. Uncoated noodles, Konjac gum coated noodles (KGN) and gellan gum coated noodles (GGN) were cooked and immersed in broth for 30-120 s and compared in terms of conductivity of soluble ions in artificial saliva during multiple extrusion cell (MEC) analysis, as well as color, texture and sensory attributes. Results showed that conductivities of KGN, GGN and uncoated noodles increased by 146%, 124% and 182% respectively after 30s of soaking in broth. No significant ($p > 0.05$) relationship between immersion time and conductivity was observed. Textural analysis showed significant ($p < 0.05$) differences between uncoated noodles and KGN in terms of hardness. KGN were the softest, followed by GGN and uncoated noodles. Coating of noodles significantly ($p < 0.05$) reduced noodles adhesiveness and tensile strength. Color analysis showed KGN as being significantly ($p < 0.05$) lighter, but no significant difference ($p > 0.05$) in redness and yellowness between samples. There was significant relationship ($p < 0.05$) between the immersion duration of noodles with the color changes. As the immersion duration of noodles in broth increased, the lightness (L-values) decreased, while redness and yellowness values increased. Sensory analysis showed that KGN had the highest intensity of overall flavor and saltiness ($p < 0.05$), were softer and preferable ($p < 0.05$) to the other two samples.

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1. Introduction

In many Asian countries, rice noodles are the most consumed form of rice product other than cooked rice (Ahmed, Qazi, Li, & Ullah, 2016; Fu, 2008; Pan et al., 2008). In these countries, different versions of rice noodles are produced, but the basic three ingredients remain rice flour, water and salt (Juliano, 1993; Fu, 2008). Other starches, such as tapioca starch, potato starch, high-amylose maize starch etc., may be added during the rice noodle making process to enhance the appearance, texture and cooking properties of noodles (Wang et al., 2020; Lubowa, Shin, & Azhar, 2018). The rice noodles are easy to cook, delicious, offer convenience and several nutritional benefits to the consumer (Kim, Kee, Lee, & Yoo, 2014; Lubowa et al., 2018). To enjoy the rice noodles, each mouthful of noodles must be accompanied by a spoonful of broth. However, rice noodles have low imbibing property and flavor from broth is poorly adsorbed. Thus, the enjoyment of a rice noodle dish is reduced by the bland flavor of rice noodles.

Currently no study on flavor adsorption by rice noodles is found in literature. The objective of this study was to enhance broth flavor adsorption of rice noodles by coating the rice noodle surface with selected hydrocolloids which were thought to increase imbibing property of noodles. Hydrocolloids, also known as gums, comprise of a diverse group of long chain polymers. They are called hydrocolloids because of their characteristic property of forming a dispersion/ or gel when dispersed in water, which is intermediate between a true solution and a suspension and exhibits the properties of a colloid (Milani & Maleki, 2012). The use of hydrocolloids in foods is gaining popularity every day (Dickinson, 2003). This is due to the fact that when used at levels ranging from a few parts per million to high levels in foods, they produce a profound impact on the properties of the food, by modifying its rheology, including basic properties such as viscosity and texture (Milani & Maleki, 2012). As such, hydrocolloids have been used as food additives to impart a wide array of functional properties to the foods including; as thickening agents in both sweet and sour sources, gravies, salad dressings, soups, sauces, ketchups and toppings (Gamonpilas et al., 2011; Krystyjan, Sikora, Adamczyk, & Tomasik, 2012; Sikora, Kowalski, Tomasik, & Sady, 2007); as gelling agents such as in puddings, cooked meats, gelled pet foods, , jellies, glazing of cakes and improvers in bakery (Guarda, Rosell, Benedito, & Galotto, 2004; Kohajdová & Karovičová, 2009); as emulsifiers in ice cream, butter and yoghourt (Kiani, Mousavi, Razavi, & Morris, 2010); as stabilizers and clarifying agents in wines and beers; and as fat replacers in diary and meat products (Pinero et al., 2008; Phillips and Williams, 2009).

Studies have also been done to demonstrate other possible novel functional uses of hydrocolloids in foods. These include enhancing cooking quality and hardness in zero-salt noodles (Tan, Tan, & Easa, 2018); enhancing shelf life of cheeses and meats (Cerqueira et al., 2010; Di Pierro, Sorrentino, Mariniello, Giosafatto, & Porta, 2011); acting as water-binding agents in gluten-free foods (Mohammadi, Sadeghnia, Azizi, Neyestani, & Mortazavian, 2014); food packaging materials (bioplastics) (Li & Nie, 2016; Nussinovitch & Hirashima, 2013).

The current study explored the feasibility of using coatings of hydrocolloids gellan gum (GG) and Konjac gum (KG) to enhance broth imbibing and flavor adsorption of rice noodles. Gellan gum is an extracellular polysaccharide produced by fermentation of Spinghomonas paucimobilis, formerly known as Pseudomonas elodea (Marceliano B Nieto, 2009; Xu, Li, Kennedy, Xie, & Huang, 2007). While konjac gum is a type of hydrocolloid derived from the root of the plant *Amorphophallus spp* (Marceliano B. Nieto, 2009). These two hydrocolloids share a characteristic of being thermally stable under high temperature (Lin & Huang, 2003; Survase, Saudagar, Bajaj, & Singhal, 2007). Thus, they would not melt after it gelled. Gellan gum can be applied in various food products such as confectionery, water-based gels, jam and jellies, pie filling, fabricated foods, dairy products and pet foods (Survase et al., 2007). Gellan gum is not only applicable in foods that require a highly gelled structure, but also suitable for uses in food systems to provide body and mouth-feel (Giavasis, Harvey, & McNeil, 2000). Gellan gum also has been used as edible coating to carry anti-browning agents that were applied on fresh cut apples (Rojas-Graü, Tapia, Rodríguez, Carmona, & Martin-Belloso, 2007). Xu et al. (2007) reported that the addition of gellan gum in rice starch gel was able to improve the hardness, adhesiveness and chewiness of the gel. The gelation of gellan gum is affected by the polymer concentration, temperature and presence of monovalent and divalent cations in solution (Survase et al., 2007; Yuguchi, Mimura, Kitamura, Urakawa, & Kajiwara, 1993). Gellan gum does not form gels in deionized water, but the addition of calcium, sodium, potassium and magnesium are able to causes an increase in gel strength and brittleness (Giavasis et al., 2000). Moreover, divalent cations are more effective than monovalent cation in gelling. Lower concentration of gellan gum is needed and a stronger gel can be obtained in the addition of divalent cations (Giavasis et al., 2000). When konjac gum is dissolved in alkaline coagulant such as calcium hydroxide, sodium hydroxide and potassium carbonate, deacetylation occurs, and a thermo-irreversible gel is formed (Lin & Huang, 2003; Thomas, 1997). KG is usually applied in food products that require thermal stability or improved elasticity and gel strength (Jean-Marc, 2010). Low effective calorie value of konjac also makes it suitable to replace high-calorie thickeners at very low use levels (Jean-Marc, 2010). For example, partial replacement of fat with konjac-gellan mixed gel in reduced-fat frankfurters had improved the textural and sensory characteristics, comparable to regular high-fat frankfurter (Lin & Huang, 2003; Cofrades et al., 2000).

In this study, it was hypothesized that when cooked fresh rice noodles are immersed in broth, the rice noodles with konjac gum and gellan gum coatings would imbibe more broth and adsorb more flavors than uncoated noodles. Besides, the overall texture of the coated rice noodles would be softer than uncoated rice noodles. The differences between gellan gum coated noodles, Konjac gum coated noodles and uncoated noodles were compared in terms of textural properties, color, conductivity of soluble ions in artificial saliva and sensory attributes. Flavor adsorption by the rice noodles was estimated through measuring the conductivity of water-soluble ions in saliva during multiple extrusion cell (MEC) analysis while sensory attributes were estimated using a ranking test.

2. Materials and methods

2.1 Materials

Ingredients used in making of rice noodles included rice flour, tapioca flour and water. Rice flour (Erawan brand, Cho Heng Rice Vermicelli Factory Co. Ltd.) and tapioca flour (Kapal ABC brand, Thye Huat Chan Sdn. Bhd.) were all purchased from Tesco store (Penang, Malaysia). The hydrocolloids selected for this study were konjac gum and gellan gum, purchased from Sim company Sdn. Bhd. Other ingredients used in making the coatings included calcium chloride which was purchase from Sim company Sdn. Bhd. (Penang, Malaysia), Sodium carbonate solution (Gold Coin, Sin Heng Lee Food Industries Sdn. Bhd.) and the instant Laksa broth powder (Sudee, World Prominence Sdn. Bhd.) were purchased from Tesco store (Penang, Malaysia). Chemicals used to prepare artificial saliva included sodium bicarbonate ($NaHCO_3$), dipotassium phosphate (K_2HPO_4), sodium chloride (NaCl), potassium chloride (KCl) and calcium chloride dehydrate ($CaCl_2.2H_20$) which were all purchased from Systerm, Classic Chemicals Sdn. Bhd. (Malaysia). Xantham gum and α-amylase used were purchased from Sim company Sdn. Bhd. (Penang, Malaysia) and Fluka (Switzerland) respectively. While hydrochloric acid (HCl) solution used to adjust the artificial saliva to pH 7 was purchased from Qrec (New Zealand).

2.2 Preparation of materials

2.2.1 Preparation of rice noodles

Rice flour (400 g or 80%) and tapioca flour (100 g or 20%) were mixed together. 400 mL of boiling water was added slowly into the mixed flour and kneaded until a homogenous elastic dough was formed. The kneaded dough was placed into a handheld extruder (Cookie press, model M21 Empire Home living, Malaysia) with a die of 3 mm diameter pore size and extruded into noodle strands. The extruded noodles were immediately boiled in boiling water for 2 min until they floated. The boiled noodles were removed with a strainer and transferred into cold water for 2 min. Noodles were then strained from the cold water and disentangled.

2.2.2 Preparation of hydrocolloid solutions for coating

2.2.2.1 Gellan gum solution

The gellan solutions was prepared according to Mao et al. (2000) with slight modification. Gellan solution (1% w/v) was prepared by dispersing 5 g of gellan gum into 500 mL of deionized water. The mixture was heated to 97–98 °C and held at that temperature for 1 min. After that, 0.55 g of calcium chloride was added and stirred for 1 min.

2.2.2.2 Konjac solution

The konjac solution was prepared according to Ding (2007) with slight modification. Konjac solution (1% w/v) was prepared by dissolving 5 g of konjac gum (KG) into 500 mL of water. The pH of the water was adjusted to pH 9–10 by adding sodium carbonate solution. The solution was boiled for 3 mins with continuous stirring.

2.2.3 Preparation of broth

The broth was prepared by following the instructions on the packaging. 900 mL of water was heated until boiling, followed by addition of 40 g of the instant broth powder. The solution was stirred until the powder was totally dissolved.

2.2.4 Preparation of artificial saliva

The artificial saliva was prepared according to the method described by Boland et al. (2004). $NaHCO_3$ (5.208 g), 1.241 g of K_2HPO_4, 0.877 g of NaCl, 0.447 g of KCl, 0.441 g of $CaCl_2.2H_2O$, 0.920 g of xanthan gum and 200,000 U of α-amylase were mixed in 1 L of distilled water. The pH of artificial saliva was adjusted to 7.0 by using 0.1 M of HCl.

2.3 Coating of the rice noodles

The noodles prepared in (2.2.1) were dipped for 2 min into the respective hydrocolloid solutions prepared in (2.2.2). After that, the noodles were drained and cooled at room temperature to allow the coating to fully gel. Noodles coated with gellan gum were labeled as GGN, those coated with Konjac gum were labeled as KGN. Uncoated noodles were used as the control in the entire study.

2.4 Determination of broth flavor adsorption/release from noodles using Multiple cell extrusion (MEC)

Generally, rice noodles are served immediately after the hot broth is poured on the cooked fresh noodles. The instant broth used in this study contained salt, sugar, citric acid, disodium 5-ribonucleotide, and other ingredients that contribute to the flavor in the broth. Therefore, to study the flavor adsorption of the noodles, cooked GGN, KGN and uncoated noodles were immersed in the hot broth for 30, 60, 90, and 120 s, after which, they were removed for analysis. Water-soluble ions were used as the indicator of flavor release from noodles during mastication. This involved determining the approximate water-soluble ions content in noodles before and after they had been immersed in the broth. To determine the water-soluble ions released from

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noodles during mastication, a multiple extrusion cell (MEC) was used as described by Foo et al. (2011); Foo et al. (2013); Janssen et al., (2009); L.-Y. Li *et al*. (2013); and Tan et al. (2016) with slight modification. MEC consists of a circular plate piston (diameter 22 mm, thickness 3 mm) with six holes (diameter 6 mm) connected via a thin rod to the texture analyzer. The rod will move up and down through a cell lid that closes the vessel. The temperature of MEC was maintained at 37 °C by using a digital heating circulator (Tech-Lab Scientific Sdn. Bhd., Protech HC-10, Selangor, Malaysia). MEC was attached to a software-controlled texture analyzer (TA-TX2 model, Stable Micro Systems, Surrey, UK) which was fitted with 30 kg load cell. The settings used were: *Mode: Measure force in compression; Option: Cycle until count; Test Speed: 10 mm/s; Post-Test Speed: 5 mm/s; Distance: 95 mm; Count:1- 15 cycle; Data Acquisition Rate: 2 pps*. 20 g of noodle sample and 10 mL of artificial saliva were placed into the cylindrical sample vessel. The noodles were then extruded for a defined number of times (from 1 time to 15 times), which mimics the chewing action of noodles in mouth for 1 to 15 times. The time taken for 15 extrusion cycles was less than 5 minutes. Saliva sampling was carried out after each extrusion cycle and the conductivities were checked to determine the relationship between the number of extrusion and release of water-soluble ions in saliva. In all cases, the saliva was collected and diluted 10 times with deionized water. A sensION+ EC5 conductivity meter and probe (Hach company, USA) were used to determine the level of water-soluble ions released from the noodles into the saliva after chewing. The conductivity meter was calibrated following the instruction of the manual before use. The conductivity probe was placed into the saliva sample solution to determine the water-soluble ions content in the saliva.

2.5 Textural properties of noodles

2.5.1 Texture profile analysis

Noodle textural properties were evaluated as described by Foo et.al, (2011) with minor modifications. A software-controlled texture profile analyzer (TA-TX2 model, Stable Micro Systems, Surrey, UK) which was fitted with 30 kg load cell was used. This was first calibrated using 5 kg load cell. The fixture used in this analysis was pasta firmness/stickiness rig. The settings used were: Mode: Texture profile analysis; Option: Return to start; Pre-Test Speed: 1.0 mm/s; Test Speed: 1.0 mm/s; Post-Test Speed: 3.0 mm/s; Strain: 75 %; Time: 2 s; Trigger Force: 0.05 N: Data Acquisition Rate: 200 pps. Cooked noodles were cut into 70 mm in length and five noodle strands were placed straight and flat adjacently to one another under the compression plate of pasta firmness/stickiness rig on the center of the platform. From the TPA curve, textural parameters of hardness and adhesiveness of the noodles were recorded.

2.5.2 Tensile strength

Noodle tensile strength was determined using a Texture Analyser (TA-XT Plus, Surrey, UK) fitted with a 5.0 kg load cell and rig arm as described by Tan et al. (2016). The sample was tested by winding both ends of the cooked noodle strand around the upper and lower rig arm slot respectively. The distance that the probe was set apart was 15 mm. The settings used were: *Mode: Measure force in tension; Option: Return to start; Pre-test speed: 3.0 mm/s; Test speed: 3.0 mm/s; Post-test speed: 5.0 mm/s; Distance: 100 mm*. Noodle thickness was first measured by using a manual micrometer (Dial thickness gauge Mitutoyo M1 7305, Takatsu-ku, Kawasaki, Japan). Tensile strength was calculated using the following equation:

$$\sigma = F/A \quad \text{(Eq. i)}$$

where, σ is the tensile strength (Pa), F is the peak force (N), and A is the cross-sectional area of the noodle strand (m^2).

2.6 Color Measurement

The surface color of noodles was measured using colorimeter (Model CM-3500D, Konica Minota Co., N.J, USA) equipped with D65 illuminant using CIE L^*, a^* and b^* color scale. The method described by Lubowa et al. (2018) was followed and measurements were performed in triplicates.

2.7 Sensory Evaluation

The sensory evaluation was performed using a ranking test involving 40 semi trained panelists recruited from the students of the Food Technology division, School of industrial technology, USM. The panelists were required to rank the samples in ascending order based on different attributes including intensity of overall flavor, saltiness, hardness, and overall preference. Simple ranking test is used when the purpose of the test is to differentiate several samples according to single attribute such as sweetness, freshness, and preference (Meilgaard, Carr, & Civille, 2006). The noodles were soaked in broth for not less than 120s. The evaluation was conducted in the sensory laboratory.

2.8. Statistical analysis

Experiments were done in triplicates unless where indicated. Results were then expressed as mean values ± standard deviation. Analysis of variance (ANOVA) and Turkey's test for multiple comparisons were used to determine significant differences ($P<0.05$) among the samples. Statistical analysis was run using SPSS version 20 (IBM Corp., Armonk, U.S.A.)

3. Results and Discussion

3.1 Relationship between the number of extrusions and release of water-soluble ions in saliva.

Figures 1 to 4 shows the relationship between extrusion cycles and conductivities of water-soluble ions in saliva for noodles immersed in broth for 30, 60, 90 and 120s respectively. The samples were extruded for 1 to 15 times using MEC and the conductivities were checked after each extrusion cycle, to determine the relationship between the number of extrusion and release of water-soluble ions in saliva.

The instant broth used contained salt, sugar, citric acid, disodium 5-ribonucleotide, and other ingredients that contribute to the flavor. In water, salt which is the ionic compound will dissociate into Na^{+} and Cl^{-} and contribute to electric current (Moore, Stanitski, & Jurs, 2010). According to Holler and Enke (1996), the greater the current produced in a given electric field, the greater the conductivity of the materials which also means the higher concentration of ions in the solution. In other words, the greater the conductivity of noodles, more flavor was adsorbed on the noodles. Although citric acid is an organic acid (is not strongly dissociated), however according to the study done by Marcotte et al. (2000), citric acid is able to conduct electric current and can be detected by a conductivity meter.

For all immersion times and for each extrusion cycle, the conductivity of water-soluble ions in the saliva was in the order of KGN > uncoated > GGN. However, no significant ($p > 0.05$) relationship between the number of extrusion cycles and conductivity was observed for every immersion time. Therefore, the results of 15 extrusion cycles were used to assess the effect of hydrocolloid coatings on flavor adsorption of rice noodles. This was because 15 extrusion cycles had the highest structural breakdown and thus it was expected to have better release of the adsorbed water-soluble ions into the saliva.

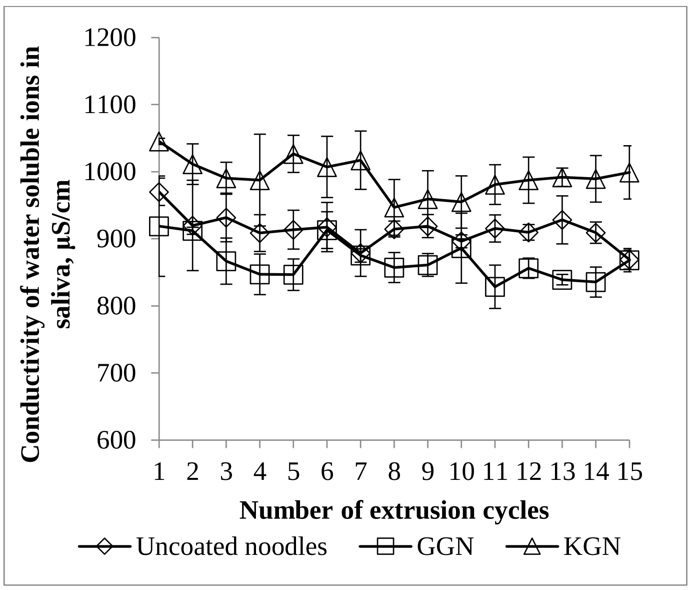

Fig. 1. Conductivity of water-soluble ions in saliva after the noodles immersed in broth for 30 s. [1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Error bars indicate the standard deviations of nine independent measurements (n=9)

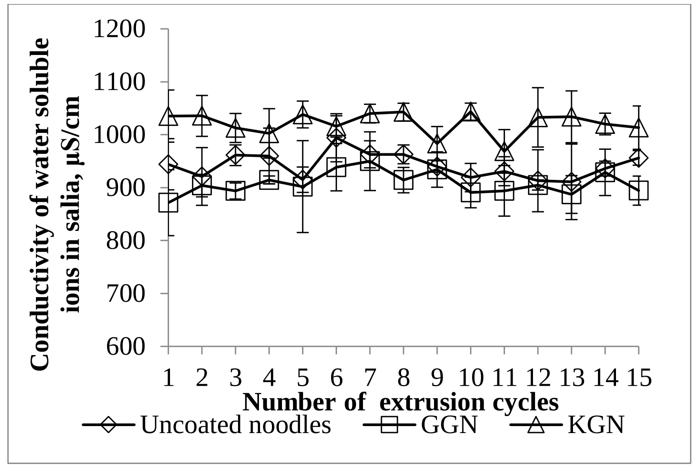

Fig. 2. Conductivity of water-soluble ions in saliva after the noodles immersed in broth for 60 s. [1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Error bars indicate the standard deviations of nine independent measurements (n=9).

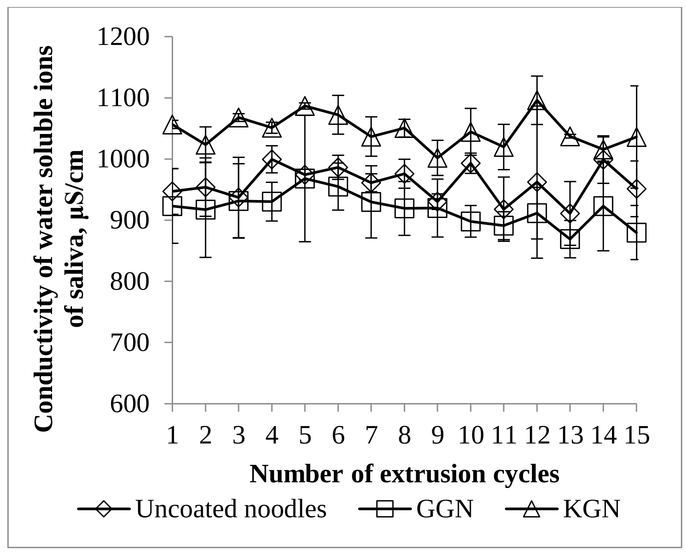

Fig. 3. Conductivity of water-soluble ions in saliva after the noodles immersed in broth for 90 s. [1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Error bars indicate the standard deviations of nine independent measurements (n=9).

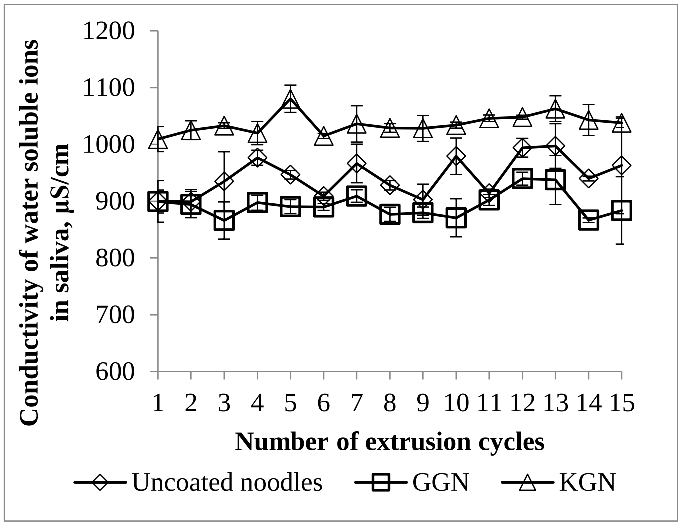

Fig. 4. Conductivity of water-soluble ions in saliva after the noodles immersed in broth for 120 s. [1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Error bars indicate the standard deviations of nine independent measurements (n=9).

3.2 Effect of coatings on flavor adsorption.

Figure 5 represents the results for conductivities of water soluble-ions of noodles at the 15th extrusion cycle after each immersion time.

At time 0 s, the conductivity of uncoated noodles, GGN and KGN were 352 ± 20.24, 387 ± 22.52 and 354 ± 53.26 µS/cm respectively. After immersion in broth for 30 s, the conductivity of noodles increased by 146%, 124% and 182% respectively. This increase in conductivity readings could be interpreted that some ions or acids had been adsorbed from the broth onto the rice noodles. However, no significant ($p > 0.05$) relationship between immersion time and conductivity was observed. The conductivity readings of noodles at 30 s of immersion time were almost similar as noodles immersed for 120 s, implying that the immersion time did not have notable effect on adsorption of ions and acid on the noodles. Conductivities started showing significant ($p < 0.05$) differences from 60 s of immersion time. This could be because 30 s was too short a time for the water-soluble ions to fully adsorb on the surface of noodles. For all immersion times, KGN always exhibited highest conductivity, followed by uncoated noodles and GGN respectively. At 120 s immersion time, the conductivities of uncoated noodles, GGN and KGN were 963 ± 85.23, 884 ± 59.34, 1038 ± 8.16 µS/cm respectively. Several explanations could be advanced for the differences in conductivities (flavor adsorption) between each sample. First, the surface area of the adsorbing surface (i.e. noodles). According to Attwood and Florence (2012), adsorption capacity of solute is mainly depended on the surface area of the adsorbent. Therefore, the surface area of noodles was calculated using following equation:

$$\text{Surface area of noodles} = 2\pi rh \qquad \text{(Eq. ii)}$$

where r is the radius of noodles and h is the length of noodles (assume the length of noodles were 10 cm for each type of samples).

Therefore, the estimated surface area of uncoated noodles, GGN, and KGN were 0.11, 0.11 and 0.12 m^2 respectively. The surface area of noodles increased as the thickness of noodles increased. KGN that had the larger surface area compared to uncoated noodles and GGN probably due to the higher viscosity of konjac solutions which resulted into a thicker layer of konjac solution coated on the noodles. Thus, more water-soluble ions and acids could be adsorbed on the surface of KGN when adsorption capacity was greater (Attwood & Florence, 2012) compared to uncoated and GGN. Surface porosity and characteristics of the coating could also lead to differences in flavor adsorption. It was observed that gellan gum formed a layer of rigid coating on the noodle surface, with less stickiness. This layer of coating might act as a barrier and inhibit the adsorption of broth including the water-soluble ions and acids. Surface barrier properties can also play a significant role in adsorption of materials (Luckett & Wang, 2012). According to Attwood and Florence (2012), the less porous the adsorbent, the less will be its adsorption capacity. Moreover, this might also be because affinity between gellan gum and the water-soluble solutes in broth was low. Konjac molecules are known to be highly hydrophilic (high affinity for water/ high water adsorption rate) (Jean-Marc, 2010; Koroskenyi & McCarthy, 2001; Zhang, Chen, & Yang, 2014). So as the water was being adsorbed on the KG, water soluble ions carried along, thus the higher conductivity in KGN compared to uncoated noodles and GGN.

3.3 Effect of Coatings on texture and tensile strength of rice noodles

Hardness, adhesiveness and tensile strength values of the coated and uncoated rice noodle samples are shown in Table 1. There were significant differences ($p < 0.05$) between uncoated noodles and KGN in terms of hardness. KGN was the softest, followed by GGN and uncoated noodles. However, no significant ($p > 0.05$) differences in hardness were observed between GGN and uncoated noodles and between KGN and GGN. Adhesiveness values showed significant ($p < 0.05$) differences among the noodle samples with the uncoated noodles being the most adhesive and GGN the least adhesive. The tensile strength of noodles decreased when coated with hydrocolloids. The tensile strength of uncoated noodles, GGN and KGN were 37,725.63 ± 3510.46, 35,306.84 ± 2632.03 and 34,247.94 ± 2725.50 N/m^2 respectively. Coatings could have yielded softer noodles compared to the uncoated ones probably due to water entrapment in the networks of konjac gum and gellan gum during the gelling process. In this case, the gelling agent would show characteristics of both liquid and solid once they are gelled (Saha & Bhattacharya, 2010). Because of the high-water absorptivity of Konjac gum, it is possible that much water was entrapped in the gel, which could lead to a softer texture of the coated noodles, meanwhile GGN showed similar characteristics to the uncoated noodles. This explanation is supported by the findings of Bouaziz et al. (2016), in which chips coated with almond gum decreased in hardness compared to uncoated chips.

Adhesiveness also known as stickiness is the work necessary to overcome the attractive force between the surface of the product and the surface of other materials with which product comes in contact (Szczesniak, 2002). During cooking of rice noodles, the starch leaches out from the noodles into the cooking water, and solubilize on noodle surface, which leads the noodles to become sticky. This does not only cause the cooking loss of noodles but also turns the cooking water into turbid (Bhattacharya, Zee, & Corke, 1999). The decreased stickiness of GGN and KGN recorded in this study might be caused by the thin layer of hydrocolloid coatings on the noodle surface. The gellan solution and konjac solution turned into rigid structures and layered the sticky surface of noodles during coating. The coating could also inhibit the starch from further leaching out.

Tensile strength is used to assess the ability of noodles to resist a force applied longitudinally without tearing (Ahmed et al., 2016). The decrease in tensile strength of coated noodles was probably due to the layer of gel on the surface of noodles which might have decreased the extendibility of noodles. KGN, which had lowest tensile strength, was suspected to be the easiest to be broken down.

3.4 Effect of Coatings and broth absorption on noodle color

Color values are presented in Table 2. At time 0s, lightness for uncoated noodles, GGN and KGN were 71.35 ± 0.71, 71.43 ± 0.36 and 72.24 ± 1.25 respectively.
The values showed color of KGN was significantly lighter ($p < 0.05$) compared to the other two samples, but no significant difference ($p \geq 0.05$) in redness and yellowness between samples. There was significant relationship ($p < 0.05$) between the immersion duration with the color changes. As the immersion duration of noodles in broth increased, the lightness (L-values) decreased, while redness and yellowness values increased. These color changes on immersion in broth are probably due to imbibition of broth onto and across the noodle surface. Imbibition is the activity of adsorption of water by particles of solid substances without forming a solution. Water potential gradient and affinity between the adsorbent and the imbibed liquid are the conditions necessary for imbibition (Rastogi, 1997).

3.5 Effect on Sensory acceptability

The sensory scores of all attributes showed a significant ($p < 0.05$) differences among noodle samples (Table 3). KGN had the highest intensity of overall flavor followed by the uncoated noodles and GGN. The overall flavors of the rice noodles were comprised of saltiness, sweetness, sourness and umami taste that came from the broth. The sensory results tended to support the result obtained for conductivities, in which KGN had adsorbed more flavor followed by uncoated noodles and GGN. This showed the reliability of using conductivity meter to estimate the flavor adsorbed on noodles. Similarly, noodle hardness results of sensory evaluation supported those from texture analysis. Panelists observed significant variations in noodle hardness, where KGN was the softest followed by GGN and uncoated noodles. Noodles coated with konjac gum scored significantly higher saltness ranking compared to gellan gum coated and uncoated noodles, an indication that more flavors had adsorbed on KGN. Overall, the sensory results showed KGN was the most preferable sample followed by uncoated noodles and GGN.

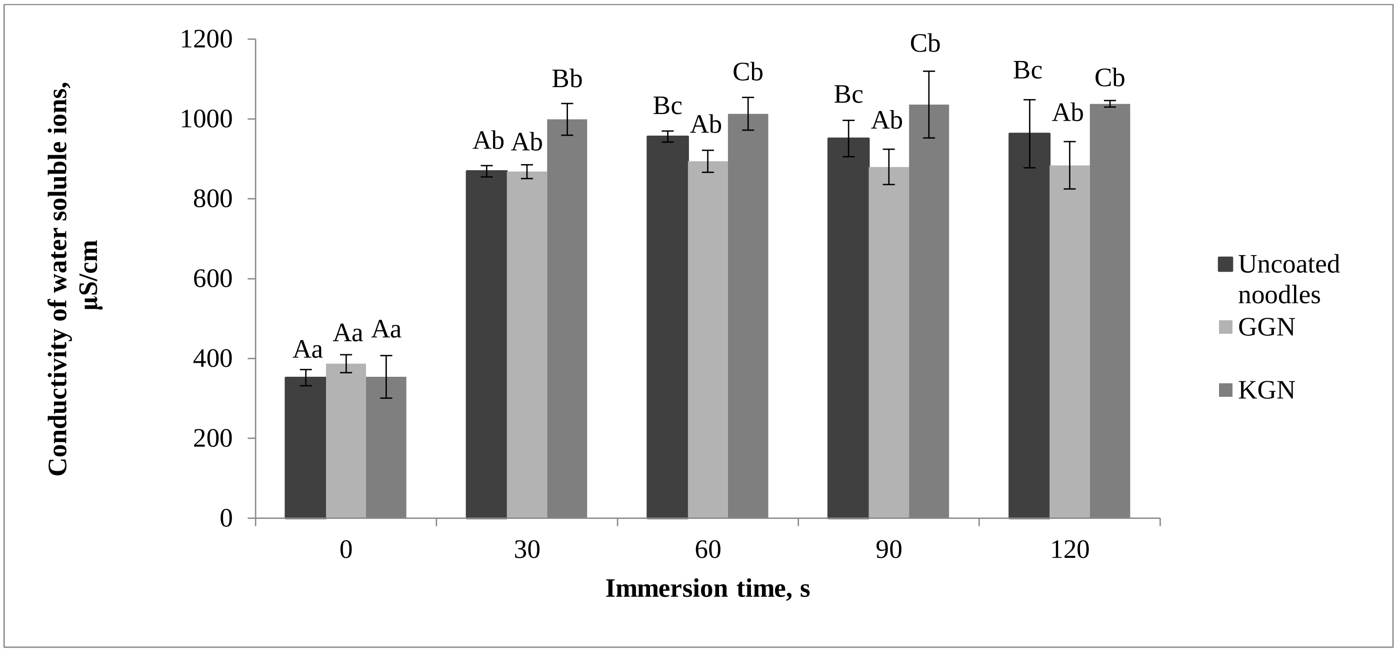

Fig. 5. Conductivity of water-soluble ions in saliva of different samples at 15 extrusion cycles after the samples were immersed for specific time. [1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Error bars indicate the standard deviations of nine independent measurements (n=9). Different uppercase superscript letters (A-C) on top of each bar indicate the significant difference ($p < 0.05$) between samples for each immersion time. Different lowercase superscript letters (a-c) on top of each bar indicate significant difference ($p < 0.05$) between conductivity of water-soluble ions in saliva for each immersion time.

Table 1: Textural properties and tensile strength of the noodles.

Sample[1]	Textural Properties		
	Hardness (g)	**Adhesiveness (g.s)**	**Tensile strength (N/m^2)**
Uncoated noodles	14,243.96 ± 878.08^{b}	4,567.09 ± 969.36^{c}	37,725.63 ± 3510.46^{b}
GGN	13,129.87 ± 2422.54^{ab}	1,619.85 ± 274.33^{a}	35,306.84 ± 2632.03^{ab}
KGN	11,537.75 ± 1834.69^{a}	3,157.66 ± 707.38^{b}	34,247.94 ± 2725.50^{a}

[1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Data were presented as mean values ± standard deviation (n=9). Different letters (a-c) superscripted after the mean values indicate significant difference ($p < 0.05$) among samples.

Table 2 Effect of coating and broth adsorption on color properties of the noodles.

Color parameters	Noodle Sample	Immersion time in seconds				
		O	30	60	90	120
L	Uncoated	71.35 ± 0.71^{Ad}	70.58 ± 0.41^{Ac}	68.81 ± 0.79^{Bb}	68.18 ± 0.32^{Bab}	67.83 ± 0.02^{Ba}
	GGN	71.43 ± 0.36^{Ad}	70.31 ± 0.48^{Ac}	67.86 ± 0.17^{Ab}	67.36 ± 0.22^{Aab}	66.76 ± 0.13^{Aa}
	KGN	72.24 ± 1.25^{Bd}	70.68 ± 0.83^{Ac}	70.12 ± 0.44^{Cbc}	69.40 ± 0.13^{Cb}	68.06 ± 0.56^{Ba}
*a**	Uncoated	-0.07 ± 0.04^{Aa}	3.57 ± 0.02^{Cb}	4.27 ± 0.12^{Bc}	4.51 ± 0.87^{Bc}	5.04 ± 0.66^{Ad}
	GGN	-0.29 ± 0.09^{Aa}	2.01 ± 0.22^{Ab}	3.54 ± 0.02^{Ac}	4.06 ± 0.25^{Ad}	5.56 ± 0.01^{Be}
	KGN	-0.33 ± 0.19^{Aa}	3.09 ± 0.70^{Bb}	3.73 ± 0.30^{Ac}	4.66 ± 0.03^{Bd}	5.33 ± 0.15^{ABe}
*b**	Uncoated	10.52 ± 0.25^{Aa}	17.49 ± 0.05^{Cb}	18.73 ± 1.10^{Bc}	18.76 ± 0.27^{Bc}	18.80 ± 0.29^{Bc}
	GGN	9.62 ± 0.18^{Aa}	14.43 ± 0.15^{Ab}	16.60 ± 0.14^{Ac}	16.71 ± 0.12^{Ac}	17.29 ± 0.20^{Ac}
	KGN	10.23 ± 0.06^{Aa}	15.59 ± 2.66^{Bb}	16.94 ± 1.30^{Ac}	17.92 ± 0.89^{Bc}	18.07 ± 1.27^{ABc}

[1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Data were presented as mean values ± standard deviation (n=9). Means with different uppercase superscript letters (A-C) in rows indicate significant difference ($p < 0.05$) between samples. Mean with different lowercase superscript letters (a-c) in columns indicate significant difference ($p < 0.05$) between immersion time for each sample.

Table 3: Sensory evaluation results of noodles.

Attributes	Uncoated noodles	GGN	KGN
Overall Flavour	2.03 ± 0.77^{ab}	1.70 ± 0.82^{a}	2.30 ± 0.76^{b}
Saltiness	1.63 ± 0.74^{a}	1.90 ± 0.81^{a}	2.48 ± 0.68^{b}
Hardness	2.60 ± 0.59^{c}	2.03 ± 0.70^{b}	1.35 ± 0.62^{a}
Preference	2.05 ± 0.75^{ab}	1.70 ± 0.85^{a}	2.23 ± 0.77^{b}

[1]GGN represents gellan gum coated rice noodles, while KGN represents konjac gum coated rice noodles. Data were presented as mean values ± standard deviation (n=40). Different letters (a-c) superscripted after the mean values indicate significant difference ($p < 0.05$)

Conclusion

From the results obtained in this work, it can be concluded that compared to gellan gum, konjac gum constituted a more promising agent for coating of rice noodles to enhance flavor adsorption. This hydrocolloid led to increased soluble ions being imbibed from broth into the noodles, which yielded higher sensory scores compared to the uncoated noodles and gellan gum coated noodles. Besides, the Konjac gum coated noodles were significantly lighter in color compared to the other samples. Despite the promising results, the texture and tensile strength values of KGN were reduced, which could present a challenge in handling of Konjac gum coated rice noodles. Therefore, further investigations for its combination with other technologies to improve product's quality should be carried out.

Conflict of interest

The authors declare no conflicts of interest.

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