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# Physicochemical properties of instant fried gluten-free noodles incorporating defatted Riceberry bran and soy protein isolate

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## Abstract

Gluten-free foods often lack proteins and fibers. This research investigated the physicochemical properties of gluten-free instant fried noodles incorporating Defatted Riceberry Bran (DRB) and soy protein isolate. The results revealed that DRB and soy protein isolate affected the pasting properties, color, cooking time and cooking yield of the noodles. However, there were no significant ($p > 0.05$) differences between the gelatinization parameters of all noodle dough samples and the cooking loss of all instant noodles. The microstructure of the gluten-free instant fried noodles containing either DRB or soy protein isolate presented a compact and dense structure which explained the longer cooking time for these samples. The addition of soy protein isolate improved the springiness of the gluten-free instant fried noodles. Therefore, the addition of DRB and soy protein isolate could improve the quality of gluten-free instant fried noodles.

**Keywords:** Gluten-free noodles; Instant noodles; Riceberry bran; Soy protein isolate; Rice flour.

## Highlights

- Defatted Riceberry Bran (DRB) and soy protein isolate improved the quality of Gluten-Free (GF) noodles
- Increased cooking yield of GF instant fried noodles with no effect on cooking loss
- Increased cooking time due to compact and dense noodle's structure
- Increased springiness of GF instant fried noodles

## 1 Introduction

Coeliac disease is a chronic enteropathy of the upper small intestine which leads to malabsorption of minerals. The only effective treatment for these patients is a Gluten-Free (GF) diet (Föste et al., 2020). GF products have seen a sudden rise in market demand (Savarese et al., 2021) which has been predicted to reach USD 32.39 billion by 2025 (Föste et al., 2020). However, GF foods are primarily based on refined flour or starch. Therefore, they often lack proteins, minerals and fibers (Miranda et al., 2014). The consumption of GF foods results in a higher sugar intake (Savarese et al., 2021). Hence, fortification with other nutritive materials is recommended, including pseudocereals, pulses and dietary fiber (Savarese et al., 2021).

Instant noodles are usually steamed and deep-fat fried products (Kruger et al., 1996). In 2019, it could be noted an estimated 106.4 billion servings of instant noodles which were consumed globally (World Instant Noodles Association, 2021). The quality of GF instant noodles could be improved by incorporating hydrocolloids (Sutheeves et al., 2020). The fortification of instant noodles with essential micronutrients (vitamins and minerals), fiber and other flours enhances their nutritional attributes (Sikander et al., 2017).

Riceberry is a Thai black rice, and it provides optimum nutritional benefit as the bran part of Riceberry contains high amounts of antioxidant compounds (Leardkamolkarn et al., 2011), protein, lipids and dietary fiber (Jiamjariyatam, 2019). The incorporation of Riceberry bran for preparing tapioca starch-based puffed cracker decreased oil absorption and expansion (Jiamjariyatam, 2019). GF rice noodles having resistant starch, inulin, and defatted rice bran (5%, w/w) significantly ($p < 0.05$) decreased the glycemic index and increased the cooking time and firmness (Raungrusmee et al., 2020). Sirichokworrakit et al. (2015) found that substitution of wheat flour with Riceberry flour decreased the stickiness, water absorption, cooking time and breaking length, while increasing the cooking loss and tensile strength of the cooked noodles. The replacement of Riceberry flour in wheat flour by up to 30% provided similar quality and a pleasant appearance as regular wheat noodle (Sirichokworrakit et al., 2015).

Soybean is a very nutritious legume containing a high percentage of high-quality proteins (about 37%), with almost all the essential amino acids (Osella et al., 2014). Proteins can improve the functional properties of food products resulting from an interaction between starch and protein (Detchewa et al., 2016). Incorporating Soy Protein Isolate (SPI) in noodles and pasta enhanced the nutritional values, digestibility properties and textural characteristic of the products (Foo et al., 2011; Rachman et al., 2019; Rachman et al., 2020). The addition of 5% SPI improved the textural properties in potato starch noodles (Takahashi et al., 1986) and GF rice spaghetti (Detchewa et al., 2016).

The current research investigated the physicochemical properties of GF instant fried noodles based on rice flour incorporating either Defatted Riceberry Bran (DRB) or SPI.

## 2 Materials and methods

### 2.1 Materials

Rice flour and SPI were supplied by Varavoot Industry Co., Ltd. (Angthong, Thailand) and Shandong Sinoglory Health Food Co., Ltd. (Qingdao, China), respectively. DRB and modified starch were obtained from R.T. Foods Co., Ltd. (Bangkok, Thailand) and Ingredion (Thailand) Co., Ltd (Bangkok, Thailand), respectively. Guar gum was purchased from Union Chemical 1986 Co., Ltd. (Bangkok, Thailand). Amylose content of rice flour was 33.77%. The protein contents of the rice flour, DRB and SPI were 8.30%, 15.13% and 92.37% dry basis, respectively. The fat contents of the rice flour, DRB and SPI were 1.34%, 0.59% and 1.66% dry basis, respectively. The total dietary fiber, insoluble fiber, and soluble fiber of the DRB were 20.8%, 19.0% and 1.76%, respectively.

### 2.2 Preparation of instant fried noodles

Rice flour (90 g), modified starch (10 g), guar gum (3 g), liquid whole egg (10 g) (egg yolks and egg whites), salt (1 g), and water (60 g) were weighed and prepared as the control. In addition, 5 g of SPI were added for the noodles having SPI (NSPI) and those containing both DRB and SPI (NDRB + SPI), while 5 g of DRB were substituted for the same weight of rice flour (DRB 5 g and rice flour 85 g) to prepare the noodles having DRB (NDRB and NDRB + SPI). The preparation method of the GF instant fried noodles was according to Sutheeves et al. (2020). The ingredients were mixed in a mixer (Kitchen Aid K5SS, USA). Then, the liquid whole egg and water containing dissolved salts were added and mixed at speed 2 for 10 mins. After that, the mixture was manually kneaded to form a dough ball and then sheeted using a pasta machine (Marcato ATLAS 150, Italy) to obtain a final thickness of 1.0 mm. This sheet was cut into strips and steamed for 10 mins. The noodles were cooled at room temperature and fried in palm oil (Morakot Industries PCL., Thailand) at 150 °C for 45 s.

## 2.3 Pasting properties

The pasting properties of the freeze-dried noodle dough samples were measured using a Rapid Visco Analyser (RVA, model 4500, Perten Instruments, Sweden) at a concentration of 12% (w/w). The standard RVA profile (RVA STD1) was used in this measurement. The sample was held at 50 °C for 1 min, heated to 95 °C at 12.16 °C/min and held at 95 °C for 2 mins 30 s before cooling to 50 °C at 11.84 °C/min and holding at 50 °C for 2 mins. The paddle speed was 960 rpm for 10 s and then decreased to 160 rpm for the rest of the cycle. Peak Viscosity (PV), Trough Viscosity (TV), Final Viscosity (FV), and Pasting Temperature (PT) were reported. Setback (SBP = FV – TV) and the Breakdown (BKD = PV – TV) viscosity were determined.

## 2.4 Thermal properties

The freeze-dried noodle dough samples were analyzed for their thermal properties using a Differential scanning calorimeter (DSC; DSC8000, Perkin Elmer, Shelton, CT, USA). An empty stainless-steel pan was used as a reference and each sample was weighed in the stainless-steel pan. Distilled water was added into the sample pan to bring the water content to 70% (w/w). The sample pan was sealed hermetically and equilibrated for 1 h at room temperature before the DSC measurement. The sample pan was heated from 25 °C to 100 °C at a ramp rate of 10 °C/min to obtain the characterization of gelatinization. The onset temperature ($T_o$), peak temperature ($T_{p1}$ and $T_{p2}$), final temperature ($T_f$) and enthalpy of gelatinization ($\Delta H$) were determined.

## 2.5 Scanning electron microscopy analysis

The cross-section images of the GF instant fried noodles were observed using Field Emission-Scanning Electron Microscopy (FE-SEM) (Tescan Mira3, Kohoutovice, Czech Republic) at an operating voltage of 5.0 kV.

## 2.6 Cooking properties

The optimum cooking time, cooking yield (or water absorption), cooking loss and rehydration time of the instant noodles were determined according to Sutheeves et al. (2020) who followed the American Association of Cereal Chemists Official Methods (American Association of Cereal Chemists, 2000) with slight modification.

### 2.6.1 Optimum cooking time

The GF instant fried noodles (10 g) were cooked in boiling water (120 mL). Boiled samples were collected and pressed with flat mirror every 15 s until any opaqueness had disappeared. The optimum cooking time was recorded.

### 2.6.2 Cooking yield

The GF instant fried noodles (15 g) were cooked in boiling water (180 mL) for the optimum cooking time as determined in 2.6.1. The cooked sample was placed on a grid for 1 min to drain excess water. The cooking yield (%) was calculated using Equation 1:

$$Cooking\ yield\ (\%) = \frac{Weight\ of\ cooked\ instant\ fried\ noodles}{Weight\ of\ instant\ fried\ noodles} \times 100 \quad (1)$$

#### 2.6.3 Cooking loss

The water portion after cooking as described in 2.6.2 was evaporated using a hot water bath, with the remaining contents dried at 105 °C for 20 h in a hot-air oven. The cooking loss (%) was determined using Equation 2:

$$Cooking\ loss\ (\%) = \frac{Weight\ of\ dried\ residue}{Weight\ of\ instant\ fried\ noodles} \times 100 \tag{2}$$

#### 2.6.4 Rehydration time

The GF instant fried noodles with a length of 5 cm (10 g) were placed in hot water (120 mL) in a beaker and the beaker was sealed using a watch glass. The rehydrated sample was taken and pressed using a flat mirror every 15 s until any opaqueness had disappeared. The rehydration time was recorded.

### 2.7 Texture profile analysis

The texture measurements of the cooked instant noodles were evaluated using a TA-XT2 texture analyzer (Stable Micro System, London, UK) and the procedure described by Sutheeves et al. (2020). The parameters obtained from the force-time curve of the Texture Profiles Analysis (TPA) were hardness, adhesiveness, springiness, and cohesiveness.

### 2.8 Statistical analysis

The experimental data were subjected to one-way Analysis of Variance (ANOVA) using the SPSS 18.0 software package (SPSS Inc., USA). Tukey's test at a significance level of $p < 0.05$ was used to compare the means.

## 3 Results and discussion

### 3.1 Pasting properties of noodle dough

The RVA parameters were correlated with the quality of cooked noodles (Yun et al., 1996). The pasting temperature represents the first stage of starch swelling, peak viscosity is the maximum viscosity of gelatinized starch, breakdown viscosity is correlated with the amount of broken starch, and setback viscosity is influenced by soluble starch (Weng et al., 2020). Ingredients, such as protein and rice bran, affect the pasting viscosity of flour (Marcoa & Rosell, 2008; Saleh et al., 2014).

The effects of DRB and SPI on the RVA values of the noodle dough made from rice flour are presented in Table 1. The results revealed that the peak viscosities decreased in the noodle dough samples containing either DRB or SPI due to the dilution of the starch component in the rice flour following the DRB and protein addition (Kim et al., 2014; Sereewat et al., 2015). The incorporation of DRB significantly decreased the breakdown viscosity of the noodle dough ($p < 0.05$), indicating the ability of the starches to withstand heating at high temperature and shear stress (Marcoa & Rosell, 2008; Thiranusornkij et al., 2019). An increase in the viscosity during cooling or setback related to the amylose crystallization that could have been affected by the protein source and dough system (Marcoa & Rosell, 2008; Kim et al., 2014). However, in the current study there were no significant differences in setback viscosities for any samples.

**Table 1.** Pasting properties of noodle dough.

| Samples | Viscosity (cP) | | | | | Pasting Temperature |
|---|---|---|---|---|---|---|
| | Peak | Trough | Breakdown | Final | Setback[NS1] | (°C)[NS] |
| Control | 6380.50 ± 14.50[a2] | 3869.00 ± 63.00[a] | 2511.50 ± 48.50[a] | 6856.50 ± 13.50[a] | 2987.50 ± 76.50 | 76.68 ± 0.08 |
| NSPI | 5313.50 ± 19.50[c] | 3164.00 ± 71.00[b] | 2149.50 ± 51.50[ab] | 6159.50 ± 55.50[b] | 2995.50 ± 15.50 | 77.03 ± 0.48 |
| NDRB | 5746.00 ± 8.00[b] | 3853.50 ± 109.50[a] | 1892.50 ± 101.50[bc] | 6670.50 ± 39.50[a] | 2817.70 ± 70.00 | 75.03 ± 0.78 |
| NDRB + SPI | 5056.50 ± 49.50[d] | 3310.00 ± 6.00[b] | 1746.50 ± 43.50[c] | 6181.50 ± 125.50[b] | 2871.50 ± 119.50 | 76.18 ± 0.43 |

[1]NS = not significantly different ($p \geq 0.05$) in same column. [2]Different lowercase superscripts in same column indicate significant differences ($p < 0.05$). Means ± standard deviation were shown. NSPI = Noodles containing Soy Protein Isolate; NDRB = Noodles containing Defatted Riceberry Bran; NDRB + SPI = Noodles containing both Defatted Riceberry Bran and Soy Protein Isolate.

### 3.2 Gelatinization properties of noodle dough

Gelatinization involves the loss of starch granule structure and disruption of the crystallinity (Luo et al., 2015). The gelatinization temperature indicates the quality of the starch crystal structure, whereas enthalpy indicates the quality and quantity of the amylopectin crystallites and the loss of molecular order within granules (Sofi et al., 2020). Table 2 shows the gelatinization parameters of the noodle dough samples. The gelatinization temperatures ($T_o$, $T_p$ and $T_f$) and enthalpies of noodle dough based on rice flour were in the ranges 64.55-88.13 ºC and 5.52-6.44 J/g, respectively, with no significant differences recorded. These results indicated that the amount of SPI and DRB used in this experiment had no effect on the gelatinization properties of the GF noodles. However, these results were higher than the gelatinization temperature (60.23-83.61 ºC) of the rice flour because the ingredients used in the noodle dough, including salt and protein, might have acted as gelatinization inhibitors by limiting water migration to starch molecules, resulting in the increased gelatinization temperature (Saif et al., 2003; Luo et al., 2015). Two values of Tp ($Tp_1$ and $Tp_2$) were detected and expressed, as shown in Table 2, because the endothermic DSC thermogram of gelatinization of all samples contained two connecting endothermic peaks (DSC thermogram not shown).

**Table 2.** Gelatinization properties of noodle dough.

| Samples | $T_o$ (°C)$^{NS1}$ | $T_{p1}$ (°C)$^{NS}$ | $T_{p2}$ (°C) | $T_f$ (°C)$^{NS}$ | Enthalpy (J/g)$^{NS}$ |
|---|---|---|---|---|---|
| Control | 65.71 ± 0.76 | 71.22 ± 0.48 | 80.20 ± 0.40$^{ab2}$ | 87.29 ± 0.76 | 6.44 ± 0.17 |
| NSPI | 64.55 ± 0.54 | 70.82 ± 0.54 | 79.53 ± 0.24$^{b}$ | 86.34 ± 0.07 | 6.23 ± 0.10 |
| NDRB | 65.12 ± 0.04 | 71.50 ± 0.42 | 80.32 ± 0.35$^{ab}$ | 87.97 ± 0.14 | 6.03 ± 0.32 |
| NDRB + SPI | 66.08 ± 0.06 | 72.56 ± 0.37 | 81.06 ± 0.21$^{a}$ | 88.13 ± 0.52 | 5.52 ± 0.11 |

[1]NS = not significantly different ($p \geq 0.05$) in same column. [2]Different lowercase superscripts in same column indicate significant differences ($p < 0.05$). Means ± standard deviation were shown. NSPI = Noodles containing Soy Protein Isolate; NDRB = Noodles containing Defatted Riceberry Bran; NDRB + SPI = Noodles containing both Defatted Riceberry Bran and Soy Protein Isolate.

Steaming is a step in the production of instant noodles and can obtain pregelatinized starches (Luo et al., 2015). No noodle dough samples after steaming for 10 mins produced a gelatinization thermogram (data not shown). This indicated that the starch completely gelatinized in the GF noodles containing around 40% moisture content after steaming and was in accordance with Luo et al. (2015) who found that gelatinization enthalpy in noodles disappeared after 1-2 mins of steaming. Additionally, Guo et al. (2018) found that wheat starch was fully gelatinized at a water content of 40% after heating for only 5 mins.

### 3.3 Color of GF instant fried noodles

Color plays a critical role in the attractive appearance of foods (Zhu et al., 2010). The color parameters (L*, chroma and hue angle) of the instant noodles before and after cooking in boiling water are shown in Table 3. The shades of the control and NSPI were yellow colors, while those of NDRB and NDRB + SPI were orange red, as shown in Figure 1. The lightness of NDRB was lower than the control and NSPI. The high amount of anthocyanin pigment in DRB caused the dark noodle color (Sirichokworrakit et al., 2015). Comparing the color values of instant noodles before and after cooking, the results revealed a decrease in the chroma values in the control and NSPI after cooking (Table 3). All samples showed a decrease in hue angle after cooking. The factors that influence color attributes of noodles are the starch content, pasting characteristics, protein content and composition and ash content (Liu et al., 2003; Weng et al., 2020).

**Table 3.** Color values of GF instant fried noodles before and after boiling in water.

| Samples | Before boiling in water | | | After boiling in water | | |
|---|---|---|---|---|---|---|
| | L* | Chroma | Hue angle | L* | Chroma | Hue angle |
| Control | 86.36 ± 0.81$^{a1/A2}$ | 23.78 ± 0.70$^{b/A}$ | 73.42 ± 1.61$^{a/A}$ | 85.25 ± 0.42$^{a/A}$ | 17.50 ± 0.40$^{b/B}$ | 63.47 ± 0.11$^{a/B}$ |
| NSPI | 83.56 ± 1.98$^{a/A}$ | 27.53 ± 0.99$^{a/A}$ | 69.56 ± 2.84$^{a/A}$ | 83.25 ± 0.58$^{b/A}$ | 20.03 ± 0.40$^{a/B}$ | 63.35 ± 0.56$^{a/A}$ |
| NDRB | 39.13 ± 1.16$^{b/A}$ | 15.23 ± 0.53$^{c/A}$ | 25.58 ± 1.14$^{b/A}$ | 43.14 ± 0.35$^{c/B}$ | 15.5 ± 0.40$^{c/A}$ | 21.13 ± 0.89$^{b/B}$ |
| NDRB + SPI | 36.99 ± 1.31$^{b/A}$ | 14.39 ± 0.36$^{c/A}$ | 27.64 ± 0.33$^{b/A}$ | 42.39 ± 1.17$^{c/B}$ | 14.78 ± 0.49$^{c/A}$ | 22.30 ± 0.62$^{b/B}$ |

[1]Different lowercase superscripts in same column indicate significant differences ($p < 0.05$). [2]Different uppercase superscripts in same sample and color parameter indicate significant differences ($p < 0.05$). Means ± standard deviation were shown. NSPI = Noodles containing Soy Protein Isolate; NDRB = Noodles containing Defatted Riceberry Bran; NDRB + SPI = Noodles containing both Defatted Riceberry Bran and Soy Protein Isolate.

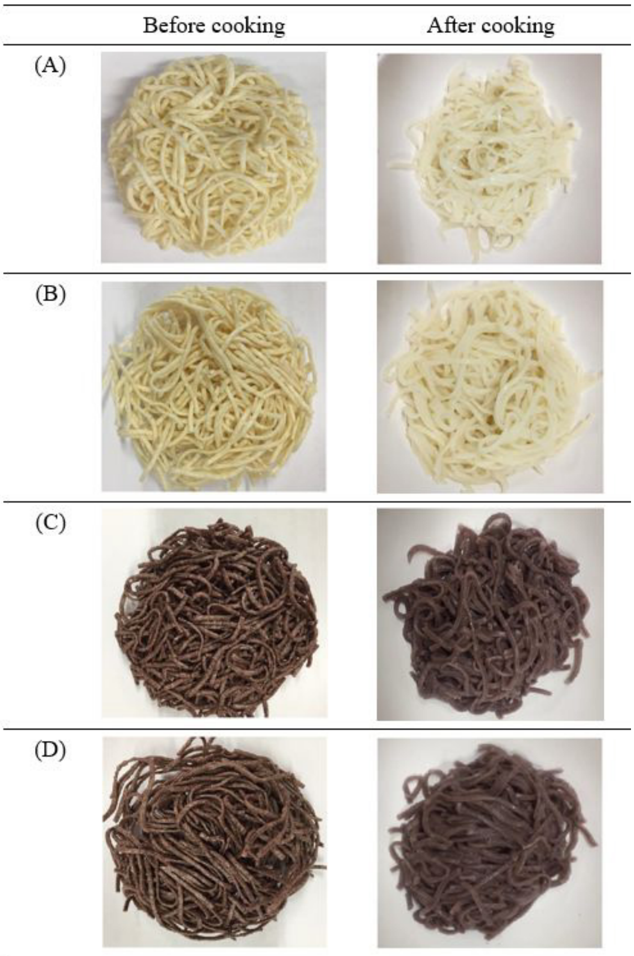


**Figure 1.** Appearance of GF instant fried noodles before and after cooking: (A) control, (B) noodles containing SPI (NSPI), (C) noodles containing defatted Riceberry bran (NDRB) and (D) noodles containing both SPI and DRB (NDRB+SPI).

### 3.4 Cooking qualities of GF instant fried noodles

Cooking quality is one of the parameters that determines noodle acceptance among consumers (Sofi et al., 2020). Good quality noodles should have a short cooking time with little loss of solids in the cooking water (Chung et al., 2012). Cooking loss indicates the ability of the noodles to maintain their structural integrity during the cooking process in hot water (Kim et al., 2014). The cooking yield relates to commercial value due to the increased weight after cooking (Weng et al., 2020).

The cooking qualities (cooking time, rehydration time, cooking loss and cooked weight) of noodles are presented in Table 4. The cooking and rehydration times of the GF noodles were in the ranges 180-255 s and 300-360 s, respectively. The incorporation of either SPI or DRB increased the cooking and rehydration times. This was attributed to the higher water absorption capacity of the soy protein (Khatkar & Kaur, 2018) and DRB (Thongkaew & Singthong, 2020), resulting in less water being available for starch swelling (Khatkar & Kaur, 2018). Cooking losses were in the range 16.12-17.19%, with no significant differences among samples. The incorporation of the DRB caused an increase in the cooking yield in accordance with Thongkaew & Singthong (2020) who incorporated Riceberry flour in rice noodles due to the higher water absorption capacity of DRB (Thongkaew & Singthong, 2020). The addition of SPI had less effect on the cooking yield, which agreed with Khatkar & Kaur (2018). Moreover, Pearson correlation analysis revealed that cooking loss negatively correlated with final viscosity measured by RVA ($r$ = -0.992, $p$ = 0.008) and cooking yield negatively correlated with breakdown values measured by RVA ($r$ = -0.981, $p$ = 0.019).

**Table 4.** Cooking qualities and textural properties of GF instant fried noodles.

| Samples | Optimum cooking time (s) | Rehydration time (s) | Cooking loss (%)[NS1] | Cooking yield (%) | Hardness (g) | Adhesiveness (g.s) | Springiness | Cohesiveness |
|---|---|---|---|---|---|---|---|---|
| Control | 180 | 300 | 16.12 ± 1.05 | 271.45 ± 8.74$^{b2}$ | 3606.46 ± 362.68$^{a}$ | -35.48 ± 0.40$^{a}$ | 0.66 ± 0.05$^{b}$ | 0.52 ± 0.04$^{a}$ |
| NSPI | 240 | 330 | 17.33 ± 1.58 | 289.39 ± 2.53$^{ab}$ | 3561.92 ± 314.09$^{ab}$ | -81.55 ± 24.00$^{bc}$ | 0.77 ± 0.02$^{a}$ | 0.47 ± 0.02$^{ab}$ |
| NDRB | 255 | 360 | 16.29 ± 1.03 | 311.62 ± 3.01$^{a}$ | 3194.14 ± 280.94$^{ab}$ | -59.92 ± 13.86$^{ab}$ | 0.71 ± 0.01$^{ab}$ | 0.45 ± 0.01$^{b}$ |
| NDRB + SPI | 255 | 360 | 17.19 ± 3.01 | 311.57 ± 28.97$^{a}$ | 3020.31 ± 414.98$^{b}$ | -94.74 ± 10.00$^{c}$ | 0.74 ± 0.05$^{a}$ | 0.46 ± 0.02$^{b}$ |

[1]NS = not significantly different ($p \geq 0.05$) in same column. [2]Different lowercase superscripts in same column indicate significant differences ($p < 0.05$). Means ± standard deviation were shown. NSPI = Noodles containing Soy Protein Isolate; NDRB = Noodles containing Defatted Riceberry Bran; NDRB + SPI = Noodles containing both Defatted Riceberry Bran and Soy Protein Isolate.

### 3.5 Microstructure of GF instant fried noodles

Figure 2 shows the cross-section microstructure of the GF instant fried noodles. SEM revealed a more uniform network and hollow structure compared to the control. The microstructures of the NDRB, NSPI and NDRB + SPI (Figure 2B, 2C, and 2D) were more compact and denser. The tighter structure retarded the ingress of water into the core of the noodles during cooking (Yao et al., 2020) and explained the higher cooking time for those samples (Table 4).

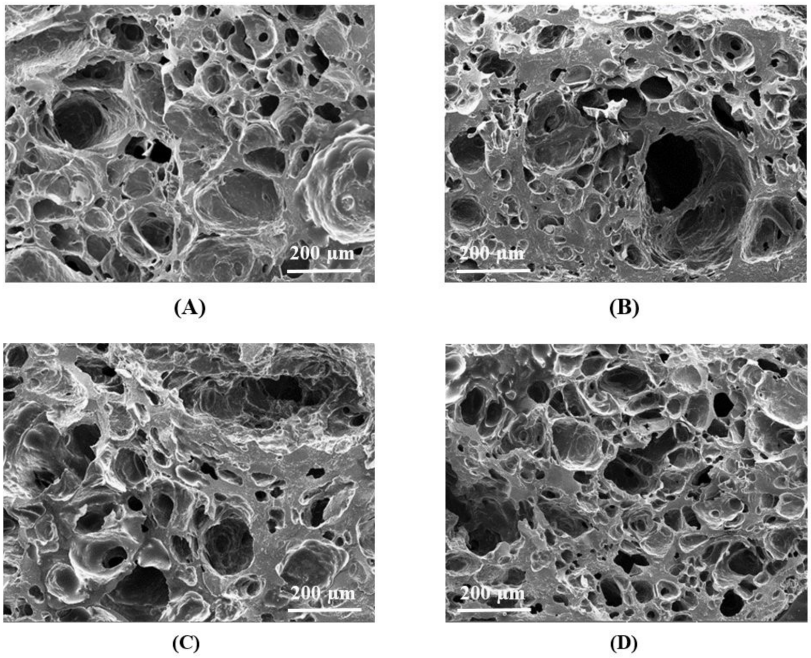


**Figure 2.** Scanning electron micrographs (200× magnification) of GF instant fried noodles: (A) control, (B) noodles containing SPI (NSPI), (C) noodles containing defatted Riceberry bran (NDRB) and (D) noodles containing both SPI and DRB (NDRB+SPI).

### 3.6 Textural properties of GF instant fried noodles

The texture of cooked noodles is a major quality attribute that determines consumer acceptance of the product (Luo et al., 2015). Hardness is the maximum force to deform the food structure. Adhesiveness reflects the stickiness of the product to the teeth while chewing. Cohesiveness is the ability of a material to stick to itself. Springiness measures elasticity (Weng et al., 2020). The textural properties evaluated using instruments correlated with the sensory properties of the GF instant fried noodles (Sutheeves et al., 2020).

The texture results of the cooked GF instant fried noodles are shown in Table 4. The GF instant fried noodles containing DRB (NDRB and NDRB + SPI) had lower hardness values than the control. This was probably related to the higher water absorption in the noodles containing DRB (Table 4). The high fiber content provided a weak structure for the cooked noodles (Thongkaew & Singthong, 2020). The samples incorporating SPI (NSPI and NDRB + SPI) had a comparable hardness to the control because hardness was positively correlated to the protein network which limited excessive water uptake during cooking (Cao et al., 2017). Compared to the control, the adhesiveness and springiness values of the noodles incorporating SPI (NSPI and NDRB + SPI) increased significantly. These results were in contrast with Khatkar & Kaur (2018) who found that the addition of soy protein concentrate in instant dried wheat noodles decreased the adhesiveness and springiness. This may have been due to differences in the ingredients, formulation, and the processing method for preparing the instant noodles in the two studies. Additionally, a highly significant negative correlation exists between adhesiveness and peak viscosity measured by RVA ($r$ = -0.997, $p$ = 0.003), showing that a high peak viscosity gives a less sticky noodle product. The cohesiveness values of the samples containing DRB were significantly lower than for the control due to the high water absorption of DBF that disrupted the noodle network (Cao et al., 2017).

## 4 Conclusion

Incorporation of RB and SPI increased the cooking time and cooking yield of the GF instant fried noodles with no effect on the cooking loss. There was a compact and dense structure for the GF instant fried noodles containing either DRB or SPI (NDRB, NSPI and NDRB + SPI). The addition of SPI improved the springiness of the GF instant fried noodles.

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