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The physicochemical and thermal properties of unripe glutinous rice flour and application in gluten-free noodle

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Abstract

The physicochemical and thermal properties of unripe glutinous rice flour (UGRF) and its potential application in rice noodles were evaluated in this study. UGRF showed dramatically higher protein content (10.57%) compared to glutinous rice flour (GRF) but was lower in amylose content. The lower peak (1647.67 cP), breakdown (661.00 cP), final viscosity (1208.33 cP), and setback viscosity (218.67 cP) were observed in UGRF ($p<0.05$). Therefore, the solubility, swelling power, and water absorption capacity of UGRF were higher than in glutinous rice flour. The onset, peak, final temperature, and especially gelatinization enthalpy was significantly different ($p<0.05$) compared to glutinous rice flour. Flour formulas for gluten-free noodle preparation were made by substituting glutinous rice flour and tapioca flour with UGRF from 0-20% (by total flour weight). The pasting properties of flour mixtures were significantly decreased with increased UGRF content. The gluten-free noodle containing 5-20% of UGRF showed a low cooking loss, high cooking weight, high maximum load, reflection at yield, and also a green-yellow colour. The porous structure of dried gluten-free noodles was increased with an increase in UGRF content, which affects the stickiness and springiness of noodles. The addition of 5-10% of UGRF showed the most appropriate properties of making gluten-free noodles with good cooking and textural properties including overall acceptance from consumers and can be used as a healthy ingredient in a variety of noodles.

1. Introduction

Generally, the consumption of rice is in the form of white rice, which has a ripening period of 28-30 days after flowering (DAF) and presents at least three-part of the grain of the panicle turn yellow with 18-21% of moisture content (Thai Agricultural Standard, 2008; Saichuk and Dunand, 2009). Rice harvesting occurs once or twice a year but only 15-21 days of the ripe grains with 30% of moisture content are suitable for producing young rice or “Khao Mao” (in the Thai language). Young rice or dough grains with undeveloped starch are still green or purple (depending on the rice cultivar) and the texture became firm like bread dough (Saichuk and Dunand, 2009). Making processed young rice or unripe rice products starts with the separation of the unripe greenish/purplish grains from the rice ears using a threshing machine or manually, and then any dirt or foreign objects are removed from the grains. The starch is allowed to be set by soaking the grains in water for a few h before steaming for about half an hour and then slowly dry-roasting over low heat for one and a half h. The cooled rice grains are then pounded in a large pestle and mortar, separating the husk and flattening the grains, the husks are blown away and processed young rice is ready for consumption. Processed young rice usually is made both from regular or glutinous rice with a variety of colours depending on a rice species that contain pigment and encourages the shades of rice such as white, green, red, or black which are mainly due to anthocyanin or chlorophyll in the plant cultivar (Chen *et al*., 2012). Processed young rice displays wonderful colours and also contains a plentiful array of bioactive compounds especially *g*-oryzanol and *g*-aminobutyric acid (GABA) (Onsaard and Banchuen, 2013). Usually, only whole grains of unripe rice can be used as an ingredient in some of the ancient Thai desserts such as an old fashion pounded unripe rice snack, sweet pounded unripe rice flakes with coconut flesh and banana, battered and deep-fried unripe rice, and grated coconut banana rolls and more. To better control, the quality of processed unripe rice-based products, the physicochemical characteristics of processed unripe rice are needed to be better understood. Recently, very few researchers have previously investigated the properties of young rice

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starch and flour. Many factors influence the physicochemical properties of rice starch such as rice cultivars (Varavinit *et al*., 2003; Yu *et al*., 2012), amylose and amylopectin content (Jane *et al*., 1999; Yu *et al*., 2009), starch composition and structure (Tukomane and Varavinit, 2008; Matalanis *et al*., 2009), processing methods (Bao *et al*., 2005), and storage conditions (Zhou *et al*., 2003). These parameters not only influence the cooking properties and eating quality of rice flour but also have a great effect on the quality characteristics of the final product. The physicochemical properties of rice starch are related to morphology, thermal, rheological, and also viscoelastic properties (Noosuk *et al*., 2005; Singh *et al*., 2006; Fari *et al*., 2011). In addition, amylose content and amylopectin branch chain-length distributions have predominately effects on the pasting properties of starch (Jane *et al*., 1999). However, there is little information about the physicochemical properties of unripe rice, therefore, the objectives of this study were to determine the physicochemical and chemical composition of UGRF from various rice cultivars in Northeastern Thailand and further study the application of unripe rice in a rice-based product. The results can bring valuable information to rice product manufacturers or food technologists to diagnose and better utilize processed young rice-based products and to encourage higher consumption. Recently, there has been a growing consumer demand for gluten-free noodle products due to their beneficial health effects such as reducing the risk of celiac disease and allergic reactions. In commercial practice, many noodles prepared from rice varieties with a high amylose content and/or chemically modified starch (with cross-linking or acetylation method) are incorporated with various hydrocolloids gum, however, the nutritional value of gluten-free noodles is still limited. As in previous studies, unripe rice contains healthy and nutritious compounds such as dietary fibres and bioactive substances in higher amounts than ordinary rice grains. The total phenolic and total flavonoids content, tocopherols, tocotrienols, g-oryzanol with high reducing power, and high protein content with a low allergic potential of unripe rice are higher than mature rice, therefore, they have a great potential for application in healthy foods (Lin and Lai, 2011; Jiamyangyuen *et al*., 2017; Pantoa *et al*., 2020). These biological components are mostly found in rice grains that are not eaten as a staple food because they can be produced only in certain seasons. Therefore, unripe rice is used as a healthy ingredient in a variety of Thai dessert noodles. In this study, the physicochemical properties of UGRF were evaluated before a partial replacement of rice flour in gluten-free noodle production and the effect of UGRF on gluten-free noodle texture and cooking qualities was also examined.

2. Materials and methods

2.1 Materials

Unripe glutinous rice samples made from the young glutinous rice (*Oryza sativa* L.) cv. RD6 was purchased from Trakanpuetpon, Ubon Ratchathani province, Thailand in August-November 2020. The stage of young rice grain development was harvested 15-21 days after the flowering date, which has 25-28% moisture content. Preparation methods for Young rice: the young RD6 grains were cleaned and soaked in tap water for 1-2 hrs, followed by steaming for 2 hrs. Then, the grains were roasted to decrease excess moisture in the grains at medium heat for 2 hrs, left to cool for 2-3 hrs at ambient temperature then pounded in a manual or motorized mortar. After pounding, the mixture was sieved and winnowed with a tray to separate young rice from the husk and fine bran. Young rice grain was dried at 60°C for 2 hrs (moisture content not higher than 14%), milled by a rice milling machine and ground through an 80-mesh sieve to produce the whole flour (13% moisture content). The flour was packed into laminated foil bags, sealed, and kept at 4°C until analysis. All chemicals used in the analysis and the determination of the chemical composition of UGRF were of analytical grade.

2.2 Physicochemical properties

Moisture, ash, protein, lipid, crude fibre, and carbohydrate of young rice were determined according to the method of AOAC (2000). The colour of UGRF was determined using a CIE colour system (Hunter, Colour Flex, USA). Colour values such as L* (brightness), a* (redness-greenness) and b* (yellowness-blueness) are measured by using white standards to calibrate the colourimeter before measurements. The water activity (aw) of the samples was determined using the Aqua lab dewpoint water activity meter (Aqua Lab, USA). The amylose content of UGRF was determined according to AACC (1999) with slight modification. The 0.1 g of UGRF was added with 1 mL of 95% ethanol and 9 mL of 1 N NaOH, mixing well and then heated for 10 mins in a boiling water bath. Then, 5 mL of the cooled-down starch solution was transferred to a 100 mL volumetric flask before 2 mL of 1 N acetic acid and 2 mL of iodine solution were further added. Finally, the volume was adjusted with distilled water to 100 mL, then stand for 20 mins at ambient temperature. The absorbance was measured at 620 nm using a spectrophotometer and the amylose content was then calculated. The chlorophyll content of UGRF was measured by extracting the chlorophyll from a UGRF sample using acetone before calculating the chlorophyll concentration by

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spectrophotometrically measuring absorption at 663 nm and 645 nm (AOAC, 1990). The swelling power and solubility index were evaluated according to the method of Wang *et al*. (2015) and Wang *et al*. (2016) with slight modifications. Flour suspension (2% w/v) was heated in a water bath at 90°C for 30 mins, then centrifuged for 15 mins, the supernatant was removed, the sediment was weighed and aliquots of supernatant were dried in an oven at 105°C until constant weight. The swelling power (%) and solubility (%) was calculated. Water absorption capacity (WAC) was determined according to Bhat and Riar (2017) by 1 g of the flour vortexed with 10 mL of distilled water or oil for 30 s in a centrifuge tube. The solution was allowed to stand at room temperature for 30 mins, centrifuged and the volume of supernatant was measured in a 10 mL graduated cylinder.

2.3 Pasting properties

The pasting properties were measured using a Rapid Visco Analyzer (RVA-4D, Newport Scientific, Warriewood, Australia) following the method described by Sandhu and Singh (2007). Flour (3 g at 14 % moisture basis) was directly weighed into an RVA specimen chamber, and distilled water was added to obtain a sample weight of 28 g. The sample was stored at 50°C for 1 min, then heated up to 95°C in 7.5 min and held at 95°C for 5 mins, followed by a cool down to 50°C in 7.5 mins, and finally held at 50°C for 2 mins. The rotating speed was maintained at 160 rpm during the process. Three replicate samples were analyzed. Parameters including peak viscosity, final viscosity, breakdown, and setback were recorded.

2.4 Thermal properties

Thermal properties were determined using a differential scanning calorimeter (*DSC*, Mettler Toledo, DSC1/400W, Japan) (Sandhu and Singh, 2007). Flour (3 mg) was loaded with distilled water into a hermetically sealed aluminium pan. The sample pans were allowed to stand for 1 hr at room temperature so that the temperature of the water is evenly distributed prior to heating the calorimeter. An empty aluminium pan was used as the reference, and the calorimeter was calibrated with indium. The scanning temperature range was 20-120°C at a heating rate of 10°C/min, then the onset (T_o), peak (T_p), conclusion (T_c) temperatures, and the enthalpy (ΔH) of gelatinization of the starch was calculated automatically.

2.5 Preparation of gluten-free noodles

The ingredients for making gluten-free noodles were rice flour, tapioca flour and glutinous rice flour (Red fish brand) were purchased from a commercial source. UGRF was used to substitute glutinous rice flour (the mixing ratio of flour composites is shown in Table 1) and other ingredients for all formulas were kept constant. For gluten-free noodle preparation, the procedure was to mix 1000 g of flour mixes of rice flour and glutinous rice flour/UGRF (according to the formula) with hot water for 5-15 mins in the Kitchen-Aid mixer to get the dough. Then, made the dough into a gel by steaming it for 15 mins and mixed with tapioca flour, kneading for 5-10 mins until a smooth texture was achieved. Then the dough was formed into a rectangular shape and transferred to a Marcato pasta-making machine (Atlas 150, Italy) to roll into a sheet and cut into gluten-free noodle strands 2.5 mm wide.

Table 1. Noodle formulation

Flour ingredients	UGRF 0%	UGRF 5%	UGRF 10%	UGRF 15%	UGRF 20%
Rice flour	45	47.5	45	42.5	40
UGRF	0*	5	10	15	20
Tapioca flour	45	47.5	45	42.5	40

*Use glutinous rice flour 10% instead of UGRF

2.6 Analytical methods for gluten-free noodles

The colour was evaluated using a Chroma meter (Hunter, Colour Flex, USA). The texture was evaluated in terms of tensile strength by a Texture analyzer (LLOYD texture analyzer model LRSK, UK). The cooking quality of the gluten-free noodles was investigated according to the method AACC (2000). The sensory evaluation of the gluten-free noodles was conducted by forty panellists, who were students and staff members in the Department of Agro-Industry, Ubon -Ratchathani University, Thailand and they are all very familiar with the kind of product. Randomly coded samples were served individually to the panellists. Six sensory attributes were evaluated (appearance, colour, odour, taste, texture and overall acceptability) using a 9-point hedonic scale for each trait, where 9 = excellent and 1 = extremely poor. Scanning electron micrographs (SEM) were obtained using a JEOL, JSM-5410LV scanning electron microscope (JEOL Ltd., Tokyo, Japan). Samples were coated with gold using a sputter coater (model SPI-MODULETM Sputter Coat). An accelerating potential of 20 kV was used during electron micrography.

2.7 Data analysis

All experiments and analytical measurements were run in triplicate. The means of each parameter were analyzed by analysis of variance (ANOVA). All data in the tables are expressed as means ± standard deviation. The results were subjected to statistical Duncan's analysis on SPSS 17.0 (SPSS Inc. US Chicago) to determine whether there was a significant difference (P <

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0.05) in each attribute.

3. Results and discussion

3.1 Physicochemical properties of unripe glutinous rice flour

The proximate compositions and physical characteristics of UGRF and ripe glutinous rice flour are compared in Table 2. The ripening stage of harvesting exhibits a significant difference in chemical composition especially protein and fat content amongst young rice and glutinous rice ($p<0.05$). UGRF shows the green colour from chlorophyll content with higher a* and b* in comparison to mature glutinous rice flour. On the other hand, glutinous rice flour contains a higher amylose content (5-7%), carbohydrate content (79.35%) and lightness (L*) than UGRF. Young rice is supposed to be in the soft dough stage, in which carbohydrate accommodation in the florets is less than a mature stage or hard dough stage. Normally, most varieties of rice are uniformly light green colours at the milky stage of the grain changes to a mixture of shades of brown and green during the dough stage. Therefore, maturity occurs when carbohydrate is no longer translocated to the panicle, most greenish grains diminish and the endosperm of all grains becomes uniformly hard and translucent (Saichuk and Dunand, 2009). However, in the previous studies, there is no information about altering the protein content of the grain during the grain-filling stage. Our study shows that UGRF contains a higher protein content (10.57%) but a lower fat content (1.58%) compared to glutinous rice flour. When the starch slurry is heated above the gelatinization temperature, the starch granules swell and leach into the solution (Fari *et al*., 2011). Therefore, the degree of swelling and the solubility index depends on the chemical bonding within the starch granules (Zhou *et al*., 2002). The present of amylose, protein, and fat content in starch inhibits the swelling extension of starch granules for one of many reasons, amylose network formation or disulfide bonding of protein or fat coating on starch granules, subsequently limits the water absorption of starch molecules (Aprianita *et al*., 2009). However, the solubility index, swelling power, and water absorption capacity of UGRF were higher than glutinous rice flour. The results suggested that as amylose content (5-7%) of GRF is higher than UGRF (4.67%), it limits the swelling capacity of starch granules, which in turn restricts the amount of starch fluids leaching into the solution. Nevertheless, the above results may be attributed not only to amylose, lipid, and protein content but also to another reason that needs further study for more explanation. Theoretical background solubility analysis revealed evidence of interactions between water molecules and starch chairs in amorphous and crystalline domains. The amylose content and the proportion of outside chains of amylopectin mainly stabilize the gel structure of starch granules to remain water and influence the swelling power and the solubility index of starch (Tang *et al*., 2005; Wang *et al*., 2015). Therefore, the lower the amylose content presented in UGRF, the less compact the starch granules and the starch is easier to overflow outside the granules and consequently higher solubility values. The swelling power of starch depends on the water adsorption capacity of the starch molecules influenced by the hydrogen bonding of amylose and

Table 2. Proximate composition and physical characteristics of unripe glutinous rice flour and glutinous rice flour

Characteristics (wb)	Unripe glutinous rice flour	Glutinous rice flour
Moisture (%)	10.66±0.19^{b}	12.50±0.29^{a}
Fat (%)	1.58±0.09^{b}	5.60±0.21^{a}
Protein (%)	10.57±0.26^{a}	1.70±0.11^{b}
Ash (%)	1.43±0.01^{a}	0.45±0.03^{b}
Fiber (%)	1.07±0.16^{a}	0.40±0.19^{b}
**Carbohydrate (%)	74.88±0.34^{b}	78.40±0.85^{a}
a_w	0.64±0.01^{a}	0.66±0.05^{a}
L*	85.65±0.12^{b}	98.22±1.03^{a}
a*	-1.50±0.30^{a}	-0.56±0.17^{b}
b*	19.93±0.25^{a}	2.41±0.31^{b}
Amylose content (%)	4.67±0.20^{b}	5-7^{a}
Chlorophyll content (%)	1.46 ± 0.06	n.d
Solubility index	23.78±0.08^{a}	7.67±1.75^{b}
Swelling power	48.27±0.32^{a}	34.37±0.20^{b}
Water absorption capacity	96.00±1.00^{a}	46.00±0.00^{b}

Values are presented as mean±SD of three replicates. Values with different superscript within the same row are significantly different according to LSD test (P<0.05).

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amylopectin (Adebooye and Singh, 2008). UGRF presents higher water holding capacity compared to glutinous rice flour suggesting that UGRF contains a more hydrophilic part from a protein to bind with water molecules (Wang *et al*., 2015). The pasting properties of starch are considered one of the most important parameters specified for evaluating the starch's properties in any rice. The viscosity profile or gelatinization pattern of UGRF and GRF observed by using Rapid Visco Analyser (RVA) shows a significant ($p<0.05$) difference for all of the pasting parameters (Table 3), which normally is affected by several parameters such as amylose, lipid contents, and branch chain-length distribution of amylopectin (Jane *et al*., 1999b). Peak viscosity (PV) indicates the highest viscosity yield of starch during gelatinization under specified conditions. The particle shape of UGRF could be influenced by its production, especially the steaming and roasting process. Our previous study found that the characteristic of UGRF particles was polyhedral shapes and agglomerate due to gelatinization occurring during its production. For that reason, a lower PV was observed in UGRF (1647.67 cP) ($p<0.05$) as the results reflects the ability of starch granules to swell freely before decomposition due to the higher lipid content, which may result in the formation of amylose-lipid complexes, therefore, a higher pasting temperature and higher resistance to shear-thinning of starch paste (Jane *et al*., 1999a). However, the lower lipid content of UGRF shows a lower PV (1647.67 cP). Moreover, the presentation of lipids and protein in UGRF has effects on the pasting properties of UGRF that encircle the starch granules and inhibit the water absorption of starch resulting in the pasting rate dramatically decreasing (Martin and Fitzgerald, 2002). UGRF had a lower breakdown and setback viscosity than glutinous rice flour indicating that its paste is more stable and has a lower tendency to retrograde. The pasting properties of UGRF show that the flour remains stable during the cooking and cooling processes. This result can be explained by a number of reasons such as UGRF contain a higher protein content and lower amylose content than GRF and the production of UGRF especially the steaming and roasting process is an effect on their granules integrity which is similar to pre-gelatinization effects. UGRF production can be Gelatinization properties of flours measured by differential scanning calorimetry (DSC) are revealed in Table 3. The onset thermal transition temperature of UGRF is lower than the onset gelatinization temperature of glutinous rice flour (55.66 and 58.75°C) probably due to UGRF presenting an incomplete structure with a shorter average branch chain length resulting in displaying a lower gelatinization temperature than glutinous rice flour. Several studies with rice starches, taro starch, and waxy maize starches have shown that those with shorter long-B chains reveal lower gelatinization temperatures (Asaoka *et al*., 1985; Shi and Seib, 1992; Shi and Seib, 1995). The gelatinization enthalpy of UGRF changes (-1.52 mJ/g) is dramatically influenced by a low percentage of crystalline amylopectin. Starch with a longer branch chain length, such as waxy maize and potato starch, needed larger amounts of energy to gelatinize crystallites of the branch structure (Jane *et al*., 1999b).

3.2 Pasting characteristic of flour blends

The pasting characteristic of flour blends composed of UGRF, rice flour, and tapioca flour with different proportions is determined. The change in viscosity of flour blends during the pasting process could be used for the prediction of noodle qualities (Table 4). The results showed that an increase of UGRF (5-20 g/100 g) in flour composites resulted in a decrease in the peak viscosity and final viscosity of flour blends this was caused by

Table 3. Pasting and thermal properties of unripe glutinous rice flour and glutinous rice flour

	Unripe glutinous rice flour	Glutinous rice flour
Pasting properties		
Peak viscosity (cP)	1647.67 ± 73.33^{b}	5694.66 ± 70.26^{a}
Breakdown viscosity (cP)	661.00 ± 6.00^{b}	2071.33 ± 26.08^{a}
Final viscosity (cP)	1208.33 ± 10.02^{b}	4416.67 ± 66.51^{a}
Setback viscosity (cP)	218.67 ± 19.65^{b}	719.00 ± 52.31^{a}
Pasting Temperature (°C)	55.76 ± 0.93^{b}	64.12 ± 0.48^{a}
Thermal properties		
T_o (°C)	55.66 ± 0.57^{b}	58.75 ± 0.12^{a}
T_p (°C)	56.04 ± 0.07^{b}	65.77 ± 0.37^{a}
T_c (°C)	60.27 ± 0.33^{b}	71.27 ± 0.81^{a}
ΔH (mJ/g)	-1.52 ± 0.36^{b}	-39.37 ± 0.35^{a}

Values are presented as mean±SD of three replicates. Values with different superscript within the same row are significantly different according to LSD test ($P<0.05$).

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Table 4. Pasting characteristic of unripe glutinous rice flour blends for gluten-free noodles preparation.

Characteristics	UGRF 0	UGRF 5	UGRF 10	UGRF 15	UGRF 20
Peak Viscosity (cP)	3168.33±92.64^{a}	2988.00±93.57^{b}	2935.67±31.50^{b}	2870.00±22.53^{bc}	2766.33±60.71^{c}
Trough Viscosity (cP)	2455.33±27.97^{a}	2276.00±27.73^{b}	2142.33±29.67^{c}	1984.00±66.84^{d}	1954.00±60.77^{d}
Breakdown (cP)	679.67±7.37^{a}	585.33±11.71^{b}	553.33±31.02^{b}	472.67±16.65^{c}	415.67±14.36^{d}
Final Viscosity (cP)	3516.00±74.50^{a}	2971.67±9.86^{b}	2866.00±15.58^{c}	2777.33±14.01^{d}	2719.00±40.95^{d}
Setback (cP)	1047.33±7.76^{a}	1014.67±8.02^{b}	991.67±11.84^{c}	926.67±22.81^{c}	851.67±5.03^{d}
Pasting Temp (°C)	69.08±0.05^{a}	69.03±0.66^{a}	69.33±0.72^{a}	68.80±0.26^{a}	68.90±0.43^{a}

Values are presented as mean±SD of three replicates. Values with different superscript within the same row are significantly different according to LSD test (P<0.05). UGRF = unripe glutinous rice flour, UGRF 0 = glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 5 = unripe glutinous rice flour:rice flour: tapioca flour = 5: 47.5: 47.5, UGRF10 = unripe glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 15 = unripe glutinous rice flour: rice flour: tapioca flour = 15: 42.5: 42.5, UGRF 20 = unripe glutinous rice flour: rice flour: tapioca flour = 20: 40: 40

UGRF becoming partially gelatinized in the starch. This may be due to the disruption of the molecular order within the starch granules due to the loss of granulation integrity and destruction of starch crystallinity (Bourekoua *et al*., 2016). The setback is indicative of the retrogradation tendency of amylose content in starch. The retrogradation of the flour mixture substituted with UGRF was reduced probably due to the low amylose content contained in UGRF. The reason is similar to starch degradation by enzyme *α*-amylases, *β*-amylases, limit dextrinase, and α-glucosidase causing starch chains to become fragmented into smaller dextrins and displayed as viscosity reduction (Fincher, 1989). In general, the lower pasting viscosity shows a higher cooling loss and inferior easting quality of starch products. Therefore, depending on the UGRF substitute treatment could be possible to obtain a different degree of gelatinization and consequently different levels of viscosity could be useful for gluten-free noodle production.

3.3 Gluten-free noodles

The pasting properties of composite flours presented in Table 2 are advantageous to predict the quality of the noodles substituted with the UGRF. Increasing the ratio of UGRF shows a decrease in peak viscosity, break down and final viscosity of the flour mixture in rice noodles formulas. Moreover, the colour and appearance of gluten-free noodles are considered to be important factors for consumer acceptance. Replacing 5-20 g of UGRF in gluten-free noodle preparation appears to decrease the lightness (L*) whilst also increasing the greenness (a*) and yellowness (b*) (Table 5, Figure 1-B, C) due to increased chlorophyll content. The colour changes in the noodle product are remarkable and attributed to the natural pigments, chlorophyll, presented in UGRF. The cooking loss, cooking weight, and water absorption are important features defining the cooking quality of noodles. The noodles prepared with flour substituted with UGRF had better cooking quality than the noodles without UGRF (control). UGRF substituted for glutinous rice flour 5-20 g/100 g has a significant effect on cooking loss, cooking weight, water absorption, and texture attribution of noodles probably due to the short-chain length fraction of UGRF which may easily leach out during cooking and allow the water molecules

Table 5. Physical characteristics of gluten-free noodles prepared from unripe glutinous rice flour

Characteristics	UGRF 0	UGRF 5	UGRF 10	UGRF 15	UGRF 20
*L**	66.32±0.06^{a}	63.55±0.23^{b}	63.24±0.03^{b}	62.66±0.03^{bc}	61.39±0.24^{c}
a*	-1.26±0.04^{c}	-3.14±0.32^{b}	-3.44±0.03^{b}	-3.79±0.06^{b}	-4.33±0.16^{a}
b*	4.49±0.21^{e}	7.54±0.03^{d}	12.65±0.12^{c}	15.29±0.09^{b}	17.48±0.23^{a}
Maximum load (N)	0.018±0.005^{b}	0.025±0.003^{a}	0.026±0.003^{a}	0.026±0.005^{a}	0.026±0.002^{a}
Deflection at yield (mm)	24.52±2.19^{d}	30.03±2.36^{c}	32.83±2.74^{c}	38.76±7.25^{b}	48.39±6.08^{a}
Cooking time (min)	4.00±0.00^{a}	4.00±0.00^{a}	4.00±0.00^{a}	3.00±0.00^{b}	3.00±0.00^{b}
Cooking weight (g)	146.21±2.52^{c}	145.42±3.53^{d}	153.57±5.68^{b}	152.57±2.75^{b}	155.55±1.13^{a}
Cooking loss (g)	3.24±0.03^{a}	3.14±0.02^{a}	2.46±0.03^{b}	2.17±0.00^{b}	1.87±0.00^{c}
Water absorption capacity	46.53±0.37^{e}	49.09±0.32^{d}	53.90±0.56^{c}	56.67±0.18^{b}	58.51±0.13^{a}

Values are presented as mean±SD of three replicates. Values with different superscript within the same row are significantly different according to LSD test (P<0.05). UGRF = unripe glutinous rice flour, UGRF 0 = glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 5 = unripe glutinous rice flour:rice flour: tapioca flour = 5: 47.5: 47.5, UGRF10 = unripe glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 15 = unripe glutinous rice flour: rice flour: tapioca flour = 15: 42.5: 42.5, UGRF 20 = unripe glutinous rice flour: rice flour: tapioca flour = 20: 40: 40

https://doi.org/10.26656/fr.2017.7(1).924

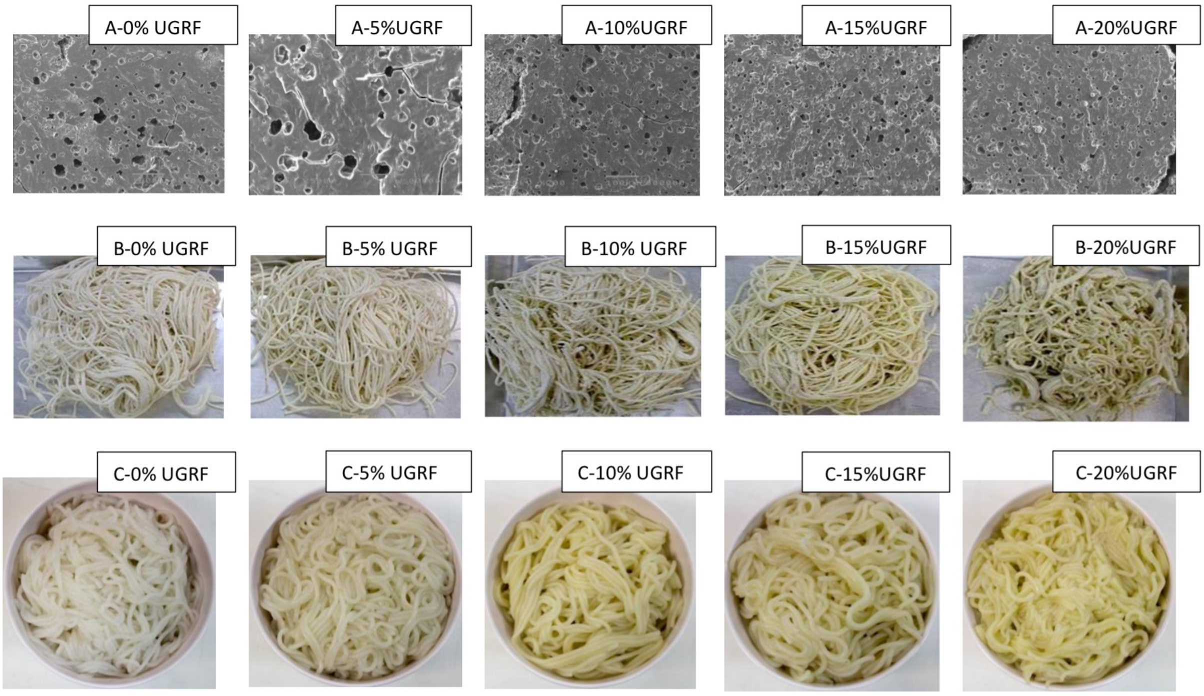

Figure 1. Electron micrograph of gluten-free noodles at 200× magnification (A), dried gluten-free noodles with different UGRF content (B), cooked gluten-free noodles with different UGRF content (C).

to penetrate readily into the noodles matrix, causing an increase in weight gain and water absorption. It seems that the water uptake of the noodles using a higher ratio of UGRF decreased the starch content inside the noodles strands, but some leached out and formed H-bonds between strands. Therefore, the strands of noodles become sticky after they had been cooked and cooled down (Figure 1C). This result suggests that increasing UGRF affects the surface H-bonds of noodle strands as a result of the increased accessibility of more UGRF to form interfacial interactions on noodles strands. Thus, the H-bonding from starch that leached out provides more bonding on the surface of noodles which encourages stickiness. An increase in UGRF causes an increase in cooking weight and water absorption of gluten-free noodles whilst also causing a decrease in cooking loss. This result agreed with maximum load and deflection at a yield which are the main characteristics that determine the consumer acceptance of noodles. Gluten-free noodles supplemented with UGRF display a maximum load and stickiness more than the control (0% UGRF). Increasing UGRF indicates an increase in deflection at yield as springiness or elasticity of gluten-free noodles. Texture evaluation is determined using tensile tests, and the results are presented in Table 5. The cooking process exhibits an impact on the structure of noodles, especially heating and water absorption during cooking causing the noodles to have a porous structure (Tan *et al.*, 2020). The sensory evaluation result is presented in Table 6, it was found that all the samples were acceptable to the panellists. Hedonic scores for appearance, colour, flavour, taste, texture and overall acceptability for 5-10% of UGRF are not different from the control (0% UGRF). Hedonic scores of all attributes for 15-20% of UGRF are significantly lower when compared with the control (0% UGRF) and 5-10% UGRF. The light green-yellow colour, unfamiliar flavour, and texture of the noodles contributed to the panellists giving relatively low hedonic scores. A porous structure of noodles occurs by the short-chain length

Table 6. Sensory evaluation of gluten-free noodles containing different amounts of UGRF

Characteristics	UGRF 0	UGRF 5	UGRF 10	UGRF 15	UGRF 20
Appearance	7.20±1.20^{a}	7.33±1.20^{a}	6.30±1.22^{b}	5.75±1.19^{c}	5.15±1.27^{d}
Colour	6.75±1.39^{a}	6.90±1.48^{a}	6.48±1.33^{a}	5.65±1.27^{b}	5.57±1.37^{b}
Flavor	5.88±1.41^{a}	6.15±1.44^{a}	6.07±1.50^{a}	6.17±1.39^{a}	6.28±1.33^{a}
Taste	6.13±1.30^{b}	6.85±1.29^{a}	6.10±1.44^{b}	5.98±1.12^{b}	5.12±1.53^{c}
Texture	6.70±1.69^{ab}	7.23±1.38^{a}	6.33±1.43^{b}	6.30±1.36^{b}	4.93±1.65^{c}
Overall acceptability	6.87±1.45^{ab}	7.18±1.50^{a}	6.53±1.35^{bc}	6.00±1.15^{c}	6.01±1.47^{c}

Values are presented as mean±SD of three replicates. Values with different superscript within the same row are significantly different according to LSD test (P<0.05). UGRF = unripe glutinous rice flour, UGRF 0 = glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 5 = unripe glutinous rice flour:rice flour: tapioca flour = 5: 47.5: 47.5, UGRF10 = unripe glutinous rice flour: rice flour: tapioca flour = 10: 45: 45, UGRF 15 = unripe glutinous rice flour: rice flour: tapioca flour = 15: 42.5: 42.5, UGRF 20 = unripe glutinous rice flour: rice flour: tapioca flour = 20: 40: 40

fraction of UGRF leaching out during cooking and allowing the water molecules outside the starch molecule to penetrate into the noodle matrix yielding a porous structure after the drying process, which is suitable for instant noodle production. The results showed the scanning electron micrographs of the inner cross-section of dried noodles at a magnification of 200× with an increase in the number of pore cells presented in noodles with higher UGRF content (Figure 1A). The increased number of pore cells in gluten-free noodles reflects the stickiness and springiness of noodles even with decreased cooking time.

4. Conclusion

The presentation of proteins and lipids in UGRF has effects on the pasting, thermal, and physical properties of UGRF. The pasting and thermal values of UGRF are lower than that of glutinous rice flour. The replacement of UGRF in flour blends with different proportions obtained a different degree of gelatinization and viscosity, which are characteristics involved with rice noodle quality. UGRF had a lower gelatinization temperature and some aspects of pasting properties such as peak and breakdown but higher values for setback compared to glutinous rice flour. Substitution of UGRF for glutinous rice flour showed substantially improved cooking qualities of rice noodles, increased cooking weight, and decreased cooking loss comparable to the control (0% UGRF). However, for textural properties, the noodles substituted with UGRF had a weaker structure than noodles made from glutinous flour. Therefore, considering cooking properties, textural properties, and sensory evaluation we found that 10% of UGRF can be effectively used as a replacement for rice flour in making coloured noodles with health-promoting and nutritive values.

Conflict of interest

The authors declare no conflict of interest.

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