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Preparation of rice spaghetti with added defatted soy flour, modified starch and durian peel powdered by extrusion method

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ABSTRACT

This study aimed to investigate the preparation of rice spaghetti added with soy protein isolate (SPI), defatted soy protein (DSF), modified starch, and dietary fiber from durian peel powdered (DPP) produced by the direct extrusion method. The addition of SPI at 5, 10 and 15% (w/w) produced rice spaghetti with less noodle stability that easily ruptured, compared to the ones made from rice flour only. DSF at 10% (w/w) was added to improve the texture of rice spaghetti using the barrel temperature of zone 1:2:3 at 60:70:80°C. The extruded rice flour spaghetti with DSF 10% (w/w) and ester-modified starch at 3% (w/w), obtained the highest acceptance, as evaluated by sensory test. Acceptable cooking qualities were assessed against the lowest cooking loss (9.04%) and the highest tensile strength (17.47 g). The product was further added with DPP at 0, 2.5, 5, 7.5 and 10% (w/w), which showed the total dietary fiber increase from 8.13 to 24.14%. The product also showed higher antioxidant capacity. Spaghetti made with added DPP at 5.0 and 7.5% (w/w) showed a non-significant difference of overall liking, compared to the control sample (0% w/w). The cooking time, cooking weight, cooking loss, and tensile strength of both products were 11 min, 236-240%, 9.90-10.20%, and 13.24-14.92 g, respectively. In addition, the products with 2.5-10% DPP could be considered as a fiber-enriched gluten-free product.

Keywords: extruded rice spaghetti; soy protein; ester-modified starch; durian peel

1. INTRODUCTION

Pasta is a traditional food popularly consumed in America and Europe, especially in Italy. This durum wheat flour product is produced by kneading the flour with water, extruding into various shapes, and dehydrating for long term storage (Lai, 2002). Pasta can be modified into a variety of shapes and received different designations including spaghetti, macaroni, vermicelli, and lasagna. Gluten is the most significant factor affecting the cooking quality of pasta (Sozer, 2009). However, gluten may cause a celiac disease known as gluten intolerance disease in some people who consumed gluten-containing foods such as wheat, barley, or rye (Bouasla et al., 2017). The allergy is common for people in Western countries (Atteno et al., 2014). Those who suffer from the allergy should avoid food that contains a gliadin fraction of wheat, hordeins from the barley, and prolamins of rye (secalins) (Sozer, 2009). In Thailand, the pasta produced from semolina wheat is relatively expensive and needed to be imported. Rice is a potential substitute for wheat flour as it contains no gluten, offers a bland taste, and high digestibility. Rice can be used in the production of noodle that is similar to pasta (Phongthai et al., 2017), offering an alternative choice for consumers. However, the lack of gluten results in a soft texture of rice pasta. In order to create a cohesive structure that is absent in gluten-free products (Padalino et al., 2016), many ingredients have been studied for their potentials including protein, pregelatinized flour, modified starch and emulsifiers. Defatted soy flour (DSF), the by-product from the soybean oil extraction, was used to increase the protein content in rice spaghetti and resulted in acceptable rice spaghetti product (Sereewat et al., 2015).

Durian (*Durio zllbethinus* Murr.) is a well-known tropical fruit commonly found in Thailand. Most durian fruits, up to 60-70%, are consumed domestically as fresh and processed products while the remaining 30-40% are exported as fresh or frozen fruits. Thus, there is a considerable amount of durian peel waste left from the consumption. Durian peels have been used to produce various items such as insulation, briquette fuel in order to value-add the by-product and reduce the waste. In addition, chemical analysis of the Mon-thong durian peel indicated a high percentage of dietary fiber (79%) (Wanlapa et al., 2010), and high antioxidant activity as determined by high ferric-reducing activity (Toledo et al., 2008).

Extrusion, a widely used process for producing snack and pasta products, is the process of pushing food through the barrel before exiting at the end of the screw. Extrusion, a continuous process with high efficiency, uses high temperatures, shear forces and pressures. The extrusion conditions such as barrel temperature and screw speed influence the extrusion responses including pressure, torque and product temperature. These factors could potentially affect the extruded product quality (Wang et al., 2016). However, the extrusion process offers many advantages including automatic control of the process, less manual operation by a worker, reduced cost, low waste, and low water usage (Sereewat et al., 2015). The objective of this research was to produce rice spaghetti from rice flour by extrusion with the supplementation of soy protein and dietary fiber from durian peel. The product qualities including cooking quality and tensile strength were determined as well as performing the sensory evaluation of the cooked rice spaghetti.

2. MATERIALS AND METHODS

2.1 Materials

Rice flour (RF) (*Oryza sativa* L.) with amylose content around 26-30% was obtained from Charoen Kim Heng Huat Co., Ltd. DSF obtained from Thai Vegetable Oil PCL was grounded using a hammer mill (Retsch, Germany) and sieved through the sieve size of 70 mesh (210 μm). The ester-modified starch (MS), Perfectamill A.C., was supplied by National Starch and Chemical (Thailand) Co., Ltd. Soy protein isolate (SPI) D400 was supported by The Mighty Co., Ltd. (Thailand). Durian peel powdered (DPP) with an effective antioxidant concentration of 2.82 mg/mL, measured by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay (Wanlapa et al., 2015), was obtained from Thailand Institute of Scientific and Technological Research (TISTR) and then sieved with the sieve size of 100 mesh (150 μm).

2.2 Preparation of raw materials

Raw materials were prepared based on the method described by Charutigon et al. (2008). The feed moisture content was adjusted to 30% (w/w) by spraying calculated amounts of warm water at 40°C and mixed at low speed (level 1) for 25 min using a mixer (Kenwood, UK). The mixture was transferred to a bowl and wrapped with polyethylene film before being kept at room temperature for 20 min. This process was necessary to equilibrate the moisture content before feeding into the extruder.

2.3 Chemical composition and pasting profile of RF and MS

The protein and lipid contents were analyzed by AOAC 12.1.07 (2000) and 920.39C (2000). The ash and moisture contents were determined according to AACC 8-01 (2000) and 44-19 (2000) methods. Amylose content of RF was determined following Juliano's method (1971), as described in Charutigon et al. (2008). The crude fiber of DPP was determined following AOAC 935.53 (2000). The pasting properties of RF and MS slurry at 28 g dry solid/100 g slurry were analyzed using a Rapid Visco Analyzer (RVA-4SA, Newport Scientific, Warriewood, Australia). The pasting properties of the mixture (RF and MS) at 0, 1, 2, 3 and 4% (w/w) were assessed. Briefly, the slurry was stirred at 900 rpm for 10 s before the shear input was decreased and maintained at 160 rpm. The cooling and heating cycles were at 23 min, starting at 50°C for 1 min, before heating to 95°C for 7.5 min and holding for 5 min. Then the mixture was cooled to 50°C for 7.5 min and maintained for 2 min.

2.4 Extrusion and processing conditions

The extrusion of rice spaghetti was prepared using a single screw extruder (19/20 DN, Brabender Technologie GmbH & Co., KG, Germany) with the barrel length (L) of 20 D, barrel bore (D) of 19.1 mm and 4:1 screw compression ratio, as described by Sereewat et al. (2015). Three barrel zones of the extruder (1:2:3) were set at 60:80:100°C with screw speed: feeder speed at 30:30 rpm, and die diameter of 1.6 mm. Extruded rice spaghetti was dried to achieve 11-12% moisture content at room temperature (27-33°C) for 24 h and kept in the sealed polyethylene bags until further analysis. Each experiment was performed in triplicate.

2.4.1 Effects of SPI, DSF, and MS

SPI with protein content higher than 90% was used to improve the texture and increase the protein content in rice spaghetti. The studied SPI: RF ratios were 5:95, 10:90 and 15:85 (dry weight basis). Cooking quality and surface appearance of rice spaghetti before and after cooking were also assessed. The addition of SPI provided rice spaghetti with an unacceptable texture. Consequently, the supplementation of DSF at 10% (w/w) was selected for further extrusion. The selection was based on the results of Sereewat et al. (2015) since it yielded spaghetti with good cooking resistance and firmness. Consequently, rice spaghetti was produced from RF:DSF:MS at the ratios of 90:10:0, 89:10:1, 88:10:2, 87:10:3 and 86:10:4, respectively. Cooking quality, tensile strength, and surface appearance after cooking of the rice spaghetti obtained were determined and sensory evaluations were carried out by 5-point hedonic test. The optimum ratio of the mixture, based on cooking quality and texture properties, was selected for further experiments.

2.4.2 Supplementation of dietary fiber from DPP

Rice spaghetti was prepared by using RF:DSF:MS ratio of 87:10:3 with the supplementation of DPP at 2.5, 5, 7.5 and 10% (w/w), and extruded under the conditions described above. The cooking quality of the products was assessed and sensory evaluation was carried out. The rice spaghetti's dietary fiber content was analyzed using enzymatic and gravimetric methods following the methods suggested by AOAC (2000) and Prosky et al. (1988). These methods utilized Megazyme total dietary fiber assay kit and DPPH assay to determine the level of antioxidant activity. The samples were hydrolyzed with heat-stable α-amylase, protease and amyloglucosidase to remove protein and starch in the sample. All analyses were carried out in triplicate and expressed as the mean value.

2.5 Determination of cooking quality and texture analysis

Physical appearances of the rice spaghetti such as air bubbles or cracks on the surface were observed. Cooking qualities including cooking time and cooking loss were analyzed following recommendations by AACC (2000). For a cooking time, 5 g of 5-cm long rice spaghetti was cooked in 300 mL of boiling distilled water. The cooking time was determined every 10 s until the rice spaghetti is fully cooked which was measured by the glass plate-white center method (Wongsa et al., 2016). The optimal cooking time was the time that the opaque white center of the rice spaghetti disappeared. The spaghetti was boiled in 300 mL distilled water at optimal cooking time and measured the weight of cooked spaghetti. Cooking loss was measured from evaporation of water that used in cooking weight process at 105±1°C in a hot air oven and calculated by following:

$$\text{Cooking weight (CW)} = \frac{\text{weight of cooked pasta (g)}}{\text{weight of sample (g)}} \times 100 \qquad (1)$$

$$\text{Cooking loss (CL)} = \frac{\text{weight of total solid in beaker (g)}}{\text{weight of sample (g)}} \times 100 \qquad (2)$$

For texture measurement, rice spaghetti was cooked at their predetermined cooking time in boiling water, washed with 50 mL of water, and drained for 10 min before being measured for tensile strength and hardness using the Texture Analyzer (Stable Micro Systems Ltd., Surrey, UK). Parallel friction roller for a tensile test and aluminum cylinder probe compression (Sereewat et al., 2015) was also performed. Fifteen samples of the rice spaghetti were measured and the obtained values were used to calculate an average value.

2.6 Half-inhibition concentration (IC_{50})

The antioxidant activity in methanol extract of the spaghetti samples was assessed for free radical scavenging activity using DPPH following the method of Brand-Williams et al. (1995). The percentage of free radical scavenging activity was plotted against the amount of samples and IC_{50} was subsequently evaluated.

2.7 Sensory evaluation

Sensory evaluation was carried out with 20 untrained panelists who were students (12 female and 8 male students, 18-23 years old) from the Department of Agro-Industrial, Food and Environmental Technology. Samples were evaluated based on panelists' preferences of cooked spaghetti extruded with different percentages of DPP of 0, 2.5, 5, 7.5 and 10%. A five-point hedonic scale (1 = dislike very much, 2 = dislike slightly, 3 = neither like nor dislike, 4 = like slightly and 5 = like very much) were used to evaluate liking skills. The samples were cooked at their suitable cooking times in boiling water and served to the panelists who evaluated 5 spaghetti samples in random order of samples.

2.8 Statistical analysis

All experiments were performed in three replications, except for sensory evaluation (n=20). The data were statistically analyzed by using analysis of variance (ANOVA) with a complete randomized design. Differences between a means of sensory attributes; color, hardness, cohesiveness and overall acceptability were tested for significance using Duncan's new multiple range test at 95% confidence level (p<0.05) using ANOVA with randomized complete block design. The results were analyzed using SPSS 17.0 software for Windows.

3. RESULTS AND DISCUSSION

3.1 Chemical composition of raw materials and pasting profile of RF and MS

As shown in Table 1, moisture, fat, ash and protein content of RF were 10.02, 0.66, 0.38 and 6.90% (dry weight basis), respectively. Amylose content of RF was 29.71%, which is in the range that can produce noodle or rice pasta with high firmness (Jeong et al., 2016). The protein content of SPI was 94.29%, which was about two times higher than the protein content of DSF of 46.74%. DSF was used to produce SPI by removing water-insoluble polysaccharides and water-soluble sugars and subsequently centrifuged to remove crude fiber (Shallo et al., 2001). The fiber content of DPP was 73.12%, which was half of the IC_{50} at 2.82

mg/mL as indicated in the raw material preparation. Therefore, the DPP was used to increase the DF content and the antioxidant ability of the extruded rice spaghetti.

The pasting profile of RF mixed with MS is shown in Table 2. The highest peak viscosity and final peak viscosity are at 227 RVU and 192.33 RVU. These values were obtained when RF was added with MS at 4% (w/w) while 100% RF indicated the lowest viscosities of both peak and final peak viscosities. The results showed that MS could increase all peak viscosities, holding strength, breakdown, final viscosity and setback of mixed flour. As MS was ester-modified to have a retrogradation ability and stability against freezing, it was also used as a thickening agent to improve the product's viscosity (Rattanapanone, 2008).

Table 1. Chemical composition of raw material

Raw material	Moisture (%)	Fat (%)	Ash (%)	Protein (%)
Rice flour (RF)	10.02±0.17	0.66±0.01	0.38±0.03	6.90±0.07
Modified starch (MS)	15.31±0.20	0.07±0.00	0.27±0.02	0.04±0.00
Defatted soy flour (DSF)	7.86±0.45	1.16±0.25	6.63±0.05	46.74±0.30
Soy protein isolate (SPI)	6.02±0.35	0.62±0.17	4.76±0.03	94.29±0.24
Durian peel powdered (DPP)	5.27±0.12	0.44±0.02	4.04±0.07	4.34±0.05

Note: Values are mean±SD of triplicate samples (n=3)

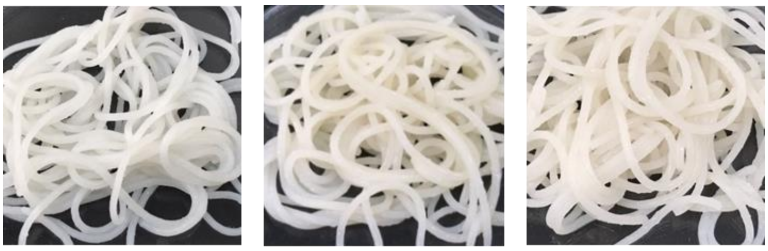
Table 2. Pasting properties of RM mixed with different percentages of MS

MS (%)	Peak viscosity (RVU)	Holding strength (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time^{ns} (min)	Pasting temperature (°C)
0	174.10±3.65^{a}	142.21±3.42^{ab}	33.42±0.23^{a}	160.07±2.94^{ab}	18.19±0.47^{b}	9.30±0.05	85.20±0.49^{c}
1	166.01±8.89^{a}	133.92±8.90^{a}	32.09±0.03^{a}	150.14±9.94^{a}	16.08±1.29^{ab}	9.43±0.04	83.08±0.10^{d}
2	191.43±0.23^{b}	153.31±1.59^{bc}	38.26±1.83^{b}	169.30±2.82^{bc}	16.34±1.23^{ab}	9.51±0.05	81.39±0.14^{c}
3	205.12±1.52^{c}	159.36±0.47^{c}	46.18±1.06^{c}	173.41±0.29^{c}	14.71±0.76^{a}	9.23±0.03	72.10±0.03^{b}
4	227.04±4.35^{d}	175.25±3.00^{d}	52.07±1.35^{d}	192.33±3.18^{d}	17.03±0.17^{b}	8.91±0.05	68.05±0.14^{a}

Note: Values are mean±SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (p<0.05)
^{ns} indicates not significant (p>0.05)

3.2 Effects of SPI, DSF and MS

The appearances of rice spaghetti samples produced from RF mixed with SPI at different percentages (5, 10 and 15% w/w) are exhibited in Figure 1. The cooking times of the samples were 8:30, 8:30 and 8:00 min, respectively. The texture of rice spaghetti after cooking was sticky. Native rice starch is not resistant to high temperature and shear force during the extrusion process which caused the breakdown of starch granules and formation of dextrins as well as short-chain polymers. This process has resulted in stickiness (Wongsa et al., 2017). The substitution of RF with a higher level of SPI led to rice spaghetti with a soft texture that can easily rupture. A similar size of the spaghetti strand was obtained while the yellowish color was observed SPI was increased. The result was in accordance with Sereewat et al. (2015) who reported that high protein content in the blend could make the pasta texture soft and split easily since the protein could interrupt the starch structure and led to more starch leaching out during the cooking process. The cooking loss of the samples tended to increase with a higher level of SPI. This finding is similar to the pasta made from sweet potato substituted with soy protein that was studied by Limroongreungrat and Huang (2007). However, adding higher-level SPI could improve the color of rice spaghetti as shown in Figure 1. Rice spaghetti was prepared from RF with 10% DSF (w/w) following the method recommended by Sereewat et al. (2015). The effects of the MS additions at 0, 1, 2, 3 and 4% on their texture's improvements and cooking qualities are shown in Table 3.



SPI 5% SPI 10% SPI 15%

Figure 1. The appearance of the cooked rice spaghetti prepared from RF with different percentages of SPI at 5, 10 and 15% (w/w)

Results show that the product with 0% MS had many bubble airs and split easily. Adding 3% MS gave the highest acceptable product with the highest tensile strength of 17.47 g, compared to the lowest tensile strength of 0% MS, at 15.21 g. This means that the higher level of MS could improve the tensile strength of the rice spaghetti significantly. The cooking time (10-11 min) and moisture content (9.55-9.83%) of all samples obtained were not significantly different. Namthongthai et al. (2018) reported that rice spaghetti's cooking time using propylene glycol alginate and soy flour by twin-screw extrusion was between 8.24-10.07 min since due to its looser structure. The cooking time of the spaghetti depended on the pasting temperature, the degree of gelatinization, and the pasting time of the mixed ingredients. The highest cooking weight of 247.89% was expressed in rice spaghetti with 2% MS while the lowest cooking weight of 206.21% was shown in rice spaghetti with 4% MS. The ester-modified starch decreased the cooking weight of the spaghetti from their reaction with the hydroxyl group of the rice starch molecules to form hydrogen bonds. The formation of hydrogen bonds led to increased strength of the starch. Therefore, water absorption and swelling of the starch were decreased (Sriroth and Piyajomkwan, 2007). The product with 4% MS indicated the lowest cooking weight with the highest cooking loss while the products from other conditions exhibited different cooking losses at 9.04-17.25%. Consequently, the mixture of RF:DSF:MS at 87:10:3 was selected for further study due to the highest tensile strength.

Table 3. Effect of modified starch on cooking quality, moisture, and texture of extruded rice spaghetti

MS (%)	Cooking Time^{ns} (min)	Cooking weight (%)	Cooking loss (%)	Moisture^{ns} (%)	Tensile strength (g)
0	10.70±0.40	243.95±6.87^{c}	10.21±0.90^{a}	9.62±0.23	15.21±1.68^{b}
1	11.30±0.57	245.30±7.73^{c}	7.43±0.28^{a}	9.76±0.09	12.86±2.07^{a}
2	11.30±0.57	247.89±5.48^{c}	9.71±3.19^{a}	9.69±0.24	14.78±3.10^{b}
3	10.70±0.40	220.18±6.19^{b}	9.04±0.77^{a}	9.83±0.04	17.47±1.07^{c}
4	10.50±0.40	206.21±7.06^{a}	17.25±2.07^{b}	9.55±0.08	15.35±2.39^{b}

Note: Values are means±SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (p<0.05)
^{ns} indicates not significant (p>0.05)

3.3 Supplementation of DPP and cooking quality and texture of extruded rice spaghetti

The supplementation of DPP at 2.5, 5, 7.5 and 10% (w/w) showed that the use of DPP at 2.5% (w/w) changed the color of the products from light yellow to dark brown when a higher quantity of DPP was added. The pasta surface was slightly rough and broken when DPP was increased to 7.5% (w/w). The cooking time of all products was about 10-11 min. A higher quantity of DPP significantly decreased the cooking weight (Table 4), which is similar to the study of Xin et al. (2018) where added curdlan (dietary fiber) decreased water absorption of noodles. This was due to cellulose's ability to decrease the hydration of flour and the pasta's lower water absorption, resulting in lower cooking weight. The products had approximately 9.55-9.83% of moisture content. Tensile strength of cooked rice spaghetti was lower with the increase of DPP, from 18.90 g (0% DPP) to 13.31 g (10% DPP). Dietary fiber in durian might interrupt the gel formation in the rice spaghetti resulted in a less cohesive pasta strand (Majzoobi et al., 2011).

The results of the sensory evaluation attempted by 20 untrained panelists using the 5-point hedonic scale test are shown in Table 5. Adding DPP at 2.5-10% (w/w) did not affect the hardness of all products, compared to the control samples (without DPP). The addition of DPP at 5-10% (w/w) did not give different cohesivenesses compared to the control samples. Overall liking scores of the product with 5 and 7.5% (w/w) DPP were not significantly different from those of the controls or the products without DPP.

Total dietary fiber in the products with different percentages of DPP are shown in Table 6, which range between 12.40 and 24.14%. The addition of a higher level of DPP led to the lower IC_{50}, which means the higher antioxidant capacity of the products. This might be due to the phytochemical components such as phenolic and flavonoid compounds in the DPP that have antioxidant activity capable of; scavenging free radicals, donating hydrogen and electrons, and providing reduced activity (Wang and Li, 2011). The percentage of Thai RDI was calculated in reference to the Ministry of Public Health (2004). One serving size for the uncooked rice spaghetti is 55 g and Thai's RDI for dietary fiber per day is 25 g. The Thai RDI fiber content in the product without DPP could be regarded as the rice spaghetti for "source of fiber" (17.88% Thai RDI). The extruded products from DPP addition at 2.5-10% could be regarded as "fiber-enriched rice spaghetti" (38.30-53.10% Thai RDI), since the supplementation of the dietary fiber is higher than 10% of Thai RDI compared to the controls.

Table 4. Cooking quality and tensile strength of extruded rice spaghetti with different percentages of DPP

DPP (%)	Cooking time^{ns} (min)	Cooking weight (%)	Cooking loss (%)	Tensile strength (g)
0	10.70±0.40	220.01±6.19^{a}	9.05±0.77^{ab}	18.90±3.11^{c}
2.5	11.00±0.00	240.24±3.53^{b}	6.93±0.70^{a}	15.73±3.78^{b}
5	11.00±0.00	236.07±5.66^{b}	9.90±0.17^{bc}	14.92±2.56^{ab}
7.5	11.00±0.00	240.19±0.15^{b}	10.20±1.74^{bc}	13.24±2.90^{a}
10	11.00±0.00	229.06±7.71^{ab}	11.90±0.81^{c}	13.31±3.14^{a}

Note: Values are mean±SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (p<0.05)
^{ns} indicates not significant (p>0.05)

Table 5. Sensory evaluation of cooked spaghetti extruded from RF:DSF:MS (87:10:3) with different percentages of DPP

DPP (%)	Color^{ns}	Hardness	Cohesiveness	Overall liking
0	3.40±0.68	3.60±1.23	3.65±1.04^{b}	3.90±1.11^{b}
2.5	2.83±1.20	2.89±1.18	2.56±0.98^{a}	2.94±1.05^{a}
5.0	3.43±0.97	3.40±0.75	3.35±0.87^{b}	3.48±0.87^{ab}
7.5	3.33±0.97	3.28±1.17	3.33±0.97^{b}	3.28±1.01^{ab}
10.0	2.79±0.97	3.00±1.05	3.00±0.88^{ab}	3.05±0.84^{a}

Note: Values are mean±SD of triplicate samples (n=20)
Different superscript letters in the same column indicate significant difference (p<0.05)
^{ns} indicates not significant (p>0.05)

Table 6. Total dietary fiber and IC_{50} of rice spaghetti with different DPP levels

DPP (%)	Total dietary fiber (%)	Thai RDI (%)	IC_{50} (mg)
0.0	8.13±0.28^{a}	17.88	344
2.5	12.40±0.78^{b}	27.28	155
5.0	17.41±0.90^{c}	38.30	118
7.5	20.93±0.80^{d}	46.04	91
10.0	24.14±2.71^{e}	53.10	68

Note: Values are mean±SD of triplicate samples (n=3)
Different superscript letters in the same column indicate significant difference (p<0.05)

4. CONCLUSION

Rice spaghetti was successfully prepared by extrusion using RF:DSF:MS at 87:10:3 ratio. Ester-modified starch was used to improve the rice spaghetti's texture and cooking quality. Supplementation of DPP at 2.5, 5, 7.5, and 10% (w/w) yielded the products with a color change from light yellow to dark brown with an increase of the DPP. The cooking time of all products obtained ranged between 10 and 11 min. The increase of DPP significantly decreased the cooking weight of the cooked rice spaghetti while their tensile strength decreased. Total dietary fiber of the rice spaghetti increased from 8.13% to 24.14% when 10% DPP was added. The products with DPP at 5 and 7.5% provided the same overall liking, compared to the controls. Thus, the products are considered as "fiber-enriched" rice spaghetti. The results suggested that the extrusion process can be used to produce the rice spaghetti, which is the gluten free product successfully.

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