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Modification of Rice Flour by Heat Moisture Treatment (HMT) to Produce Rice Noodles

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ABSTRACT

Modification of rice starch in flour from Chai Nat 1 cultivar by Heat Moisture Treatment (HMT) was evaluated for the physical and physicochemical characteristics in order to choose the modified flour to produce rice noodles. The moisture content of wet-milling rice flour was adjusted to 25%, followed by heating at 110 or 120°C for 1, 3 or 5 h to make the HMT flour. Pasting properties of native and HMT flour were evaluated by Rapid Visco Analyser (RVA). HMT120-5 flour had significantly ($p \leq 0.05$) lower peak viscosity (136.50 RVU), trough (118.67 RVU), breakdown (17.83 RVU), final viscosity (137.85 RVU) and setback (19.18 RVU) than those of native flour, while the pasting temperature of the modified rice flour (91.56°C) was significantly ($p \leq 0.05$) higher than that of native flour (80.80° C). The swelling power of modified rice flour decreased at high temperature whereas solubility was not significantly different. At 90°C, the swelling power of native and HMT120-5 flour were 12.25 and 8.93 g/g, whereas the solubility was 3.21 and 5.16%, respectively. This modification method changed HMT flour color by increasing the redness (a*) and yellowness (b*) when the holding time in hot air oven was increased. The noodles made from 10% HMT120-5 flour had higher tensile strength than the noodles made of unmodified rice flour.

Key words: heat-moisture treatment, rice, pasting property, swelling power, noodles

INTRODUCTION

Heat moisture treatment (HMT) is one of many physical methods used to modify starch. It is considered safe and has a preferred image by many consumers. This method involves treatment of starch granules at low moisture levels (<35% moisture w/w) over a period of time (about 16 h) at the temperatures ranged from 84-130 °C. This temperature range is above the glass transition temperature (T_g) but below the gelatinization temperature (Gunaratne and Hoover, 2002; Adebowale and Lawal, 2003). Heat moisture treatments change pasting properties (Liu *et al*., 2000; Anderson *et al*., 2002; Takahashi *et al*., 2005), decrease swelling power (or swelling factor) and solubility (or amylose leaching) between 60-90°C of mucuna bean (Adebowale and Lawal, 2003), potato (Perera *et al*., 1997), tuber and root starches such as true yam, taro, new cocoyam and cassava (Gunaratne and Hoover, 2002). However, the HMT waxy maize starch (Liu *et al*., 2000) and finger millet starch (Adebowale *et al*., 2005) showed an increase in solubility. In addition, they also showed no alternation in the shape or surface characteristics of starch granules

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(Perera *et al.*, 1997; Liu *et al.*, 2000) but the HMT rice starch by microwave oven asulted in slightly aggregation of starch granule (Anderson and Guruya, 2006). The alternative properties of starch or flour modified by this method suggests that it can be used as an ingredient in many food products, especially in acid foods and retorted foods (Takahashi *et al.*,2005), including the bihon-type noodles (Collado *et al.*, 2001). So, this research was aimed to produce the HMT rice flour and to provide the suitable ratio of HMT flour for improvement of the rice noodle texture.

MATERIALS AND METHODS

Rice flour preparation

Rice flour was obtained from Chai Nat 1 cultivar that was prepared by wet-milling rice flour according to the method of Lorlowhakarn and Naivikul (2006). Polished rice grains were steeped in tap water for 4 h, and then milled by wet milling method. Rice flour cake was separated from slurry by centrifugation, and after that it was dried in a tray dryer at 45±5 °C for 12 h or until the moisture content of 10% was reached. Flour was milled twice by hammer mill and passed through 100 mesh sieve. The sample was kept in the polyethylene bag, sealed and stored in cold room (4°C) until used.

Heat moisture treatment

Heat moisture condition was carried out by modifying the method of Collado *et al*. (2001). The moisture content of wet-milling Chai Nat 1 rice flour was brought to 25% and with thorough mixing during addition of water, and then placed in plastic bags, sealed and kept for 24 h at 2-4°C. Flour samples (500 g) were weighed into a stainless steel pan and then placed in an oven at 110 or 120°C for 1, 3 or 5 h. Afterwards the pan was opened, and the flour samples were dried in the tray dryer (45°C) to a uniform moisture content (<10%). The HMT flour was milled, sieve and kept in the same way as the rice flour.

Pasting properties of native and HMT flours

Pasting properties of the unmodified and the modified Chai Nat 1 rice flour dispersion in distilled water were determined using the Rapid Visco Analyser (RVA) AACC Standard method No.61-02 (AACC, 2000).

Swelling power and solubility

Swelling power and solubility were determined following the modified method of Schoch (1964). Flour samples (0.5000g, db) in 15 ml of distilled water were heated to the desired temperature (60, 70, 80 and 90°C) for 30 min in a shaking water bath, and then centrifuged at 2,288 rpm for 15 min. The supernatant was carefully removed and the swollen flour sediment was weighed. The aliquot of supernatant was evaporated at 100°C for 6 h and weighed.

Color Determination

Colorimetric measurements of samples were determined in triplicate using a spectrophotometer (CM 3500 d , Minolta Camera Co. , Ltd , Tokyo , Japan). The CIE color values were recorded as L* = lightness (0 = black, 100 = white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness).

Chai Nat 1 rice noodles preparation

The processing of Chai Nat 1 rice noodles followed the method of Suksomboon and Naivikul (2006) with some modification. Rice flour or the mixture of rice flour substituted with 5%, 10% and 20% HMT flour (40% w/w db) was mixed and stirred at every 0.5 h in water during soaking for 3 h. The slurry were divided into 2 aliquates, the first one (8 ml) was determine for viscosity at the temperature around 23°C by Brookfield viscometer (RVDV-III) using spindle no.21 at a shear rate of 90 rpm. The second (55 g) was poured onto a stainless steel tray, and then steamed for 5 min to make a noodle sheet. The noodle sheet was pulled out of the tray, rested to decrease moisture content and incubated at 2-4°C for 6 h then cut and dried at 45±5°C for 2 h. Dried noodles was kept at room temperature in a sealed polyethylene bag until used.

Tensile testing

Dried noodles was soaked with water (10 min), boiled for 15 sec, cooled and drained. One strand of rice noodle (0.4 × 23 cm) was fixed to the arms of tensile grips (A/SPR) of TA-XT2 Texture Analyser (CharPA Techcenter, and Stable Micro Systems, Ltd). Texture analysis was done within 15 min. Force and distance at break were measured for tension using 5 kg load cell with 3.0 mm/sec test speed and 60% strain (modified method of Suksomboon and Naivikul, 2006).

Morphology

Morphology of Chai Nat 1 rice flour and noodles were studied by Scanning Electron Microscope (SEM). The dried noodle was prepared in the same as the tensile testing method (above) and dehydration by freeze-drying. Samples were sputter-coated with Au using a vacuum evaporator and examined using SEM (JEOL, JSM 6310F, Japan) at 15 kV accelerating voltage using the secondary electron technique (Lorlowhakarn and Naivikul, 2006).

Statistical Analysis

Completely Randomized Design (CRD) was used as an experimental design. The SPSS for Windows program, version 10.0, was employed to analyze the results obtained from two replications. Means and standard deviations for each treatment were calculated and the analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) were used for comparing differences among mean values at the 95% confidence level.

RESULTS AND DISCUSSION

Pasting properties

Table 1 shows RVA viscogrames of CN1 and HMT flour suspension at various treatments.

The peak viscosity (136.50-286.44 RVU), breakdown (7.65-38.75 RVU) and setback (19.18-158.60 RVU) of HMT flours were lower than the native flour; whereas the pasting temperature (83.33-91.56°C) was higher. These parameters attribute to the HMT that changed the granule to a much strong and resist swelling at high temperature. Besides the low breakdown value indicated the HMT flour was durable in heat and shear.

Table 1 Pasting characteristics of native and HMT Chai Nat 1 rice flours.[1)]

Samples	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Pasting temperature (°C)
CN1[2)]	317.17 a	235.34 b	81.83 a	414.33 a	178.99 a	80.80 e
HMT110-1[3)]	286.44 b	247.69 a	38.75 b	406.29 a	158.60 b	83.33 d
HMT110-3	209.00 c	201.35 c	7.65 d	288.88 b	87.52 c	88.14 c
HMT110-5	192.29 d	184.31 d	7.98 d	256.79 c	72.48 c	88.99 bc
HMT120-1	190.89 d	171.19 e	19.69 c	211.39 d	40.19 d	89.43 b
HMT120-3	152.64 e	133.92 f	18.82 c	159.24 e	25.32 de	91.38 a
HMT120-5	136.50 f	118.67 g	17.83 c	137.85 f	19.18 e	91.56 a

1): Means within the same column followed by different letters are significantly different ($p \leq 0.05$).

2): CN1 = Chai Nat 1 rice flour.

3): HMT = Heat moisture treatment, 110 = 110°C, 120 = 120°C and 1, 3, 5 = Number of hour.

The comparison during the HMT flours, the higher temperature (120°C) and longer time process changed pasting properties of HMT flour more drastically than the lower temperature (110°C) and shorter time. The peak viscosity, trough and final viscosity of HMT110-1>HMT110-3>HMT110-5 and HMT120-1>HMT120-3> HMT120-5. When compare the effect of temperature under similar time duration during modification, the HMT120 flour had lower peak viscosity, trough, final viscosity and setback but higher pasting temperature than the HMT110 flour. These results indicated the temperature and time of modification affected on the HMT pasting characters.

Anderson *et al*. (2002) also reported similar findings in the changes of pasting properties of HMT non-waxy rice starch after exposure to heat treatment for 30 and 60 minutes. These similar pasting properties were also found in the HMT milled rice by autoclaved heating at 120°C for 60 minutes (Takahashi *et al*., 2005). However, Lai (2001) reported that the hydrothermal treatment of high amylose milled rice (28.8%) at moisture content of 22.2 and 29.8% at 75-95°C for 20-60 minutes were different, of which the final viscosity was uncertain and the setback was higher than the native ones.

These changed characteristics after the HMT processes are probably the result of the native properties of rice, the acceleration of molecular rearrangement of non-waxy rice (Lai, 2001) and amylose-lipid complex which leads to the formation of crystallites of different stabilities (Takahashi *et al*., 2005). Therefore, the treated starch granules changed structure to be stronger than the native ones, so they became extremely heat- and shear-resistant during pasting.

Swelling power and solubility

The swelling power and solubility of the unmodified and the modified rice flour at different temperatures (60-90°C) are presented in Table 2.

The swelling power of native and HMT flours increased when the temperature was raised. At 60 and 70°C, swelling power of HMT flours was higher than native flour, these results indicate that some starch granules could be pregelatinised with more susceptible to water hydration (Lai, 2001); therefore, the swelling power at the temperature below 80°C increased significantly after treatment. While the swelling values at 80°C of HMT110-3 (8.1 g/g), HMT110-5 (8.0 g/g), HMT120-3 (7.9 g/g) and HMT120-5 (7.4 g/g) flour and at 90°C of all HMT (8.9-9.9 g/g) flour were significantly ($p \leq 0.05$) lower than that of native flour (9.8 g/g at 80°C and 13.1 g/g at 90°C). The decrease in swelling power of the HMT

Table 2 Swelling power and solubility of native and HMT Chai Nat 1 rice flours at 60-90°C.[1)]

Sample	Swelling power (g/g)				Solubility (%)			
	60°C	70°C	80°C	90°C	60°C [ns]	70°C	80°C [ns]	90°C [ns]
CN1[2)]	2.7b	3.7c	9.8a	13.1a	0.7	0.8abc	2.3	4.2
HMT110-1[3)]	3.9a	4.4a	9.2ab	9.9b	0.8	0.6bcd	2.2	4.7
HMT110-3	3.7a	4.3ab	8.1bc	9.4bc	0.8	0.5d	2.3	5.2
HMT110-5	3.5a	4.1b	8.0c	9.5bc	0.9	0.7abc	1.9	4.5
HMT120-1	3.5a	4.3ab	9.5a	9.8b	0.6	0.8ab	2.0	5.0
HMT120-3	3.6a	4.2ab	7.9c	9.4bc	0.6	0.6cd	2.1	4.6
HMT120-5	3.7a	4.2ab	7.4c	8.9c	0.9	0.9a	2.4	5.2

1): Means within the same column followed by different letters are significantly different ($p \leq 0.05$).

2): CN1 = Chai Nat 1 rice flour.

3): HMT = Heat moisture treatment, 110 = 110°C, 120 = 120°C and 1, 3, 5 = Number of hour.

ns: Non significant.

flour at high temperature was related to the pasting results, of which the pasting temperature increased after treatment. These results might be due to the HMT process, which led to the acceleration of molecular rearrangement (Lai, 2001), amylose-lipid complex (Takahashi *et al*., 2005), or the degradation of the amylopectin molecules (Lu *et al*., 1996). Lu *et al*. (1996), studied gel chromatography fractionation of the hydrothermal rice starch and found that the HMT process led to the decrease in the number of large molecules (amylopectin) and the increase in the number of smaller molecules (amylose). The amylopectin has major influence in controlling the swelling of starch granules (Tester and Morrison, 1990), so the swelling power at high temperature of these HMT rice flours decreased.

The results are in agreement with the swelling factor reported by Perera *et al.* (1997) on potato starch and that of tuber and root starch reported by Guraratne and Hoover (2002). They found that the swelling factor of native and HMT starches increased with the increasing of temperature which was more pronounced at the temperatures above 70°C and they observed a decrease in swelling factor in all HMT starches.

The solubility of the native and HMT flour were not significantly different except for the HMT110-3 modified flour at 70°C. These solubility profiles of the HMT rice flours were not conformed with those observed in potato starch (Perera *et al*, 1997), tuber and root starch (Gunaratne and Hoover, 2002) and mucuna bean starches (Adebowale and Lawal, 2003). Those starches were modified under the moisture content between 16-30% at 100°C for 16 h and showed a decrease in solubility. However, Adebowale *et al.* (2005) observed an increase in the solubility of HMT finger millet starch.

Starch granule morphology

SEM with the magnification of 2,000x and 14,000x were employed to observe the starch granules of the native and the HMT flours. The starch granules had polygonal shape, both from the HMT and the native flour. However, the native starch granule had a smaller size (3.6-7.1 µm) than the HMT ones (4.1-8.5 µm). There was some fracture on the HMT starch granule surface (Figure 1d). This may be the result of heat and moisture used in modification method, which caused some swollen or partially gelatinized granules around the surface, which was supported by the result from the high swelling power at 60-70°C (3.5-3.9 g/g at 60°C and 4.1-4.4 g/g at 70°C).

Color determination

The holding time in the oven during the modification of Chai Nat 1 rice flours affected for flour color (the results are shown in Table 3). The brightness (L*) of the modified flour was not significantly different ($p>0.05$) from the native flour, whereas, the redness (a*) of HMT110-3 (0.7), HMT110-5 (0.8), HMT120-3 (0.9) and HMT120-5 (1.2), and the yellowness (b*) of all the modified flour (4.3-6.6) were higher than the native flour (a*=0.0, b*=2.8). The changed color may be caused by the maillard reaction between reducing sugar from the heated starch, and the amino group in the proteins, during modification.

These results agreed with the work reported by Takahashi *et al.* (2005), who reported the color change (increased a-and b-values) of *japonica* milled rice flour heat treated in an autoclave (120°C for 60 min) and oven (160°C for 60 min) compared with the native ones.

Rice noodle preparation, texture and morphology

Substitution of native rice flour with HMT120-5 flour at various percentages was used in the rice noodle processing to improve noodle quality. This is owing to its high pasting temperature and lowest peak viscosity of the HMT flour. Mixing of HMT120-5 flour for 5, 10 or 20 % in the flour-water slurries before steaming the

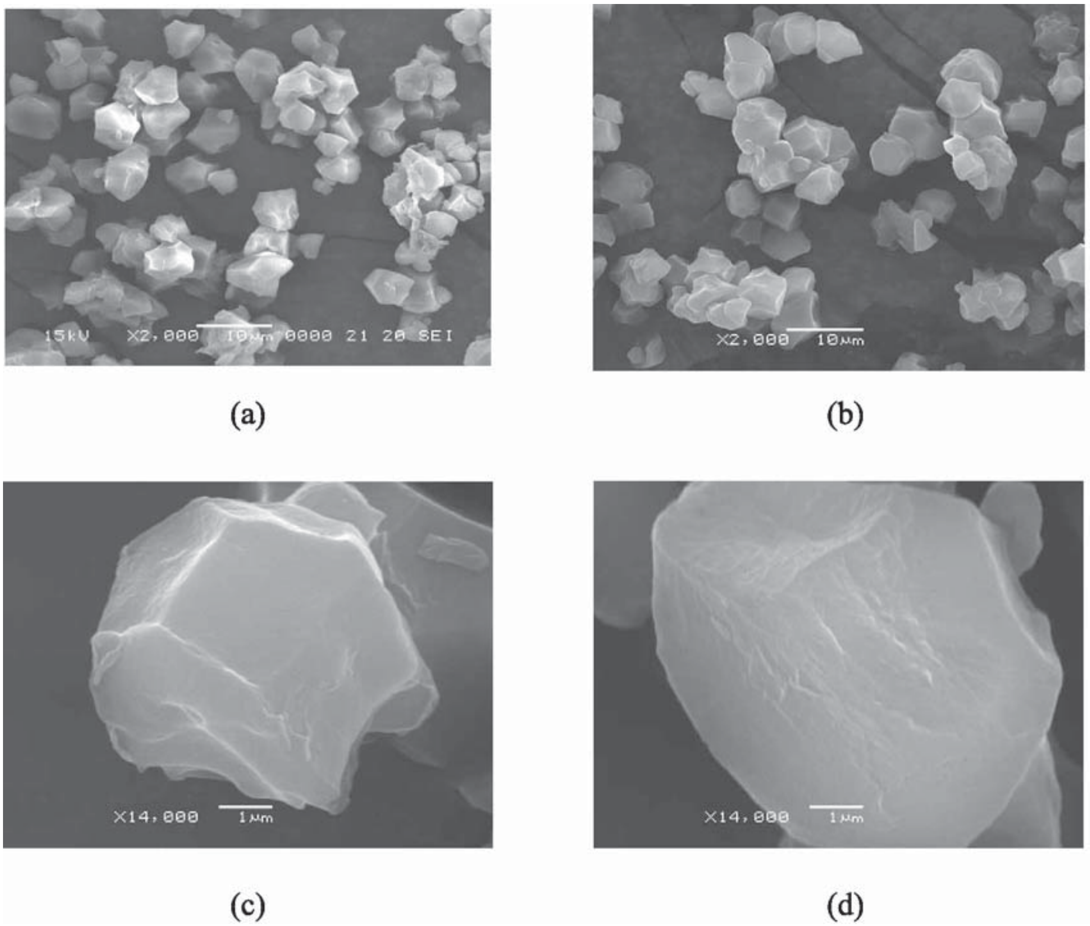

Figure 1 Starch granule of CN1 flour at 2,000x (a) and 14,000x (c), and HMT120-5 flour at 2,000x (b) and 14,000x (d).

Table 3 Color determination of native and HMT Chai Nat 1 rice flour.[1)]

Sample	Color		
	L*[ns]	a*	b*
CN1[2)]	96.4	0.0d	2.8d
HMT110-1[3)]	94.4	0.2cd	4.7c
HMT110-3	93.6	0.7abc	5.9b
HMT110-5	93.6	0.8ab	6.2ab
HMT120-1	93.1	0.4bcd	4.3c
HMT120-3	92.2	0.9ab	5.5b
HMT120-5	90.9	1.2a	6.6a

[1)]: Means within the same column followed by different letters are significantly different ($p \leq 0.05$).

[2)]: CN1 = Chai Nat 1 rice flour.

[3)]: HMT = Heat moisture treatment, 110 = 110°C, 120 = 120°C and 1, 3, 5 = Number of hour.

[ns]: Non significant.

noodle sheet increased the viscosity from 94.75 cP of CN1 to 438.50 cP of HMT120-5. This was due to HMT process attributed the flour to swell easily in 60-70°C (from the swelling power results).

Mixing of modified flour increases the noodle elasticity, shown as tensile strength (Table 4). The tension force implies the elastic limit of noodles. The 10% HMT120-5 noodles was the most elastic but CN1 and 5% HMT120-5 noodles were not significantly different (p>0.05). This may be the result from the HMT starch granule, which had a high gelatinization temperature (high pasting temperature) thus, the gelation had a lot of starch granules or ghost granules embedding within the gel matrix, which led to the hard gel. However, the substitution level as high as 20% with HMT120-5 attributed noodle to be less elastic.

These results were good agreement with Collado *et al.* (2001) who reported that the those reported by the substitution of native sweet potato starch with 50% HMT sweet potato starch in the extruded noodle increased the noodle hardness from 156g (native) to 289g (50%HMTstarch).

Furthermore, the rehydrated noodles substituted with HMT flour attributed to the incompletely gelatinized area around the center of noodle strand (shown as the smooth area in Figures 2(c) and 2(d)). This result might be a cause of increasing tensile strength of the noodle. Figures 2(d), shows that the 20%HMT noodle possessed the most incompletely gelatinized areas. This resulted in the decrease of tensile strength.

CONCLUSIONS

The holding time and temperature of HMT modification affected pasting properties, swelling power, solubility and color of HMT flours. Using high temperature and long holding times changed the HMT flour properties more than the modification at low temperature and short time. Therefore, the highest temperature and longest time treatment; i.e. HMT120-5, altered the properties of rice flour effectively. Pasting temperature of HMT flours shifted to the higher temperature but showed the decreases in the peak viscosity and setback. Swelling power of all HMT flours decreased at high temperature (80-90 °C) indicating that starch molecules had been changed; whereas the solubility of all HMT flours was nearly the same as that of native flour. The long time treatment condition of HMT flour increased the yellowness of flour. Comparing the characteristics of rice noodles from the native and HMT120-5 substituted for 10% flour, the 10% HMT noodle increased noodle tensile value.

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Table 4 Viscosity of the flour slurry before making the rice noodles and the tensile strength (force at break) of a noodle strand.[1/]

Sample	Viscosity (cP)	Tensile strength (g)
CN1	94.75 ± 5.87 d	29.6 ± 4.6 c
5% HMT120-5	275.00 ± 1.41 c	30.5 ± 6.5 c
10% HMT120-5	347.50 ± 9.19 b	74.9 ± 5.8 a
20% HMT120-5	438.50 ± 10.61 a	56.5 ± 12.8 b

[1/] Means within the same column followed by different letters are significantly different ($p \leq 0.05$)

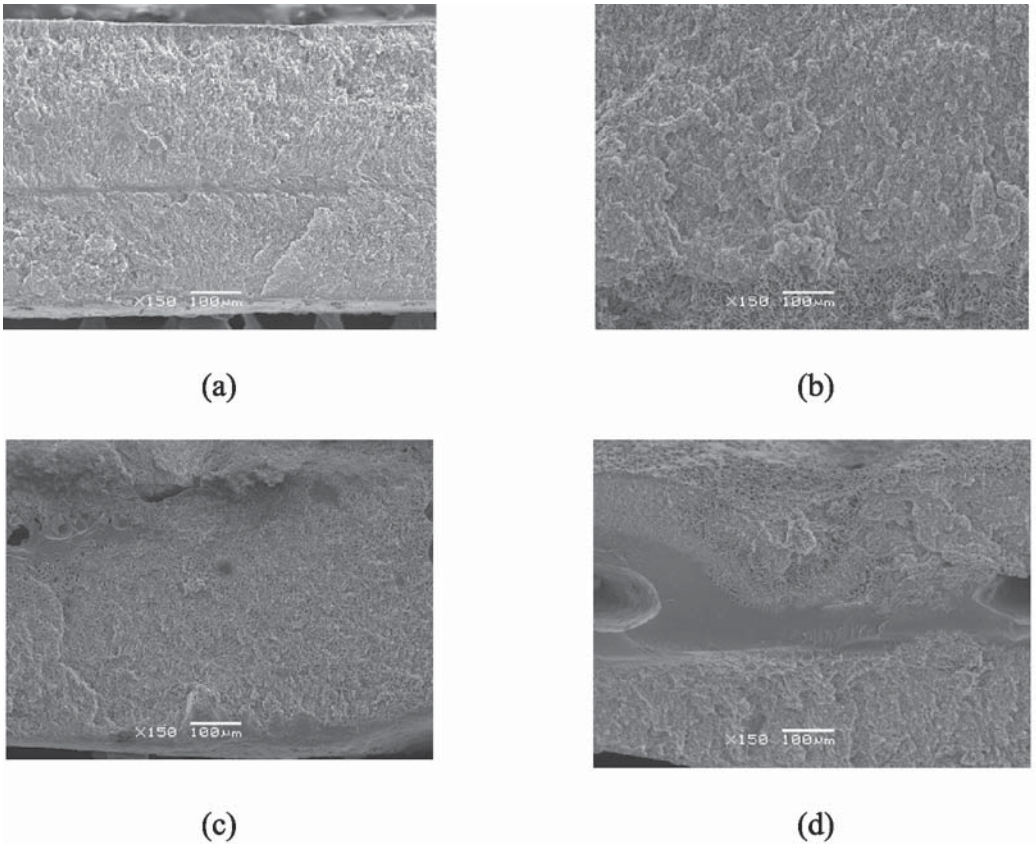

Figure 2 Morphology of the noodle strand from native (a), 5% (b) 10% (c) and 20% (d) HMT120-5 flour at 150x, using scanning electron microscope (SEM).

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