IMPROVEMENT OF RICE NOODLE QUALITY WITH OCTENYL SUCCINYLATED CASSAVA STARCH AND OCTENYL SUCCINYLATED RICE FLOUR
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Abstract: The purpose of this study is to improve rice noodle quality by using octenyl succinylated (OS) cassava starch and OS rice flour. Rice noodles were prepared by partial replacement of rice flour with OS cassava starch (degree of substitution; DS ≈ 0.017) as well as OS rice flour (DS ≈ 0.009) at levels of 10, 20 and 30% (w/w). Effects of the OS starch and flour on cooking qualities, textural properties and resistant starch (RS) content of rice noodles were investigated. Rice noodles incorporated with OS cassava starch and OS rice flour had higher cooking weight (278.2-335.6% dwb) and lower cooking loss (0.7-1.4% dwb), compared to the noodle prepared from single rice flour (control; 271.1 and 1.5% dwb, respectively). Textural analyses also indicated that the rice noodles with the modified cassava starch/rice flour had higher tensile stress (8.3-9.3 gf/m²) and elongation (60.1-92.1%) than the control (7.4 gf/m² and 54.8%, respectively). RS content of the noodles with modified products was about 3-4% higher than the control.

Introduction: Rice noodle, produced from rice flour, is one of the most popular varieties of Asian noodle and traditional oriental food widely consumed in Southeast Asia, Thailand in particular. Rice noodle is made from simple ingredients (rice flour and water) and is sometime classified by academics as “not nutritious” due to their high carbohydrate contents and calories and inadequate dietary fiber or resistant starch. Therefore, it is good for the people who need to get an energy but inappropriate for the one who have some diseases such as type-2 diabetes, obesity disease or chronic diseases.

Resistant starch (RS) refers to the portion of starch and starch products that resist digestion as they pass through the gastrointestinal tract. Resistant starch has been assigned to four categories, based on the nature of starch and its environment in food. RS1 includes physically inaccessible starch for instance in grains, such as in seeds or legumes; RS2 is granular starch, non-gelatinized sources, such as green banana flour or native potato; RS3 is indigestible retrograded starch that is formed upon retrogradation after gelatinization;RS4 is considered to be chemical modified starch, such as hydroxypropyl starch, cross linking starch and octenyl succinylated starch. RS has received much attention for both its potential health benefits and functional properties. RS acts largely through its large bowel bacterial fermentation products which are, in adults, short-chain fatty acids (SCFA) but interest is increasing in its prebiotic potential. There is also increasing interest in using RS to lower the energy value and available carbohydrate content of foods. RS can also be used to enhance the fibre content of foods and is under investigation regarding its potential to accelerate the onset of satiation and to lower the glycemic response.

Octenyl succinylated starch is usually prepared commercially by base catalyzed reaction of octenyl succinic anhydride (OSA) with granular starch in aqueous suspension. In the United States, FDA has approved OS starch for food use in 1972. The maximum level of
OSA treatment allowed is 3% (degree of substitution (DS) \( \approx 0.023 \)).\(^6\)\(^,\)\(^7\) Starches modified by OSA usually displayed higher viscosity and lower gelatinization temperature as compared to their corresponding native starch.\(^9\)\(^,\)\(^10\)\(^,\)\(^11\) The OS starch has been used by the food industry in food products such as sauces, puddings and infant formulas. Recently, OS starch was reported to have special nutritional values. Heacock et al.\(^12\) found that OSA substitution could interfere with the binding of \( \alpha \)-amylase, thus decreasing the rate and/or extent of starch digestion. Their study indicated that the nutrition use of OSA-substituted starch should attenuate the postprandial glycemic response and may decrease the caloric density of food containing it.\(^13\) Juansang et al.\(^14\) determined the RS contents of the different modified canna starches after gelatinization at 100 °C for 40 min and found that OS canna starch contained the highest RS content (45.3%), followed by hydroxypropylated (32.0%), acetylated (26.6%), and cross-linked (19.8%) and native (12.4%) canna starches, respectively.

The objective of this study was to improve the nutritional and textural properties of rice noodle by using OS cassava starch/OS rice flour. The effects of rice flour substitution with OS cassava starch/OS rice flour on resistant starch content, cooking quality and textural properties of rice noodle were investigated.

**Methodology:**

**Materials:** Rice flour was purchased from Pathum Rice Mill and Granary Public Co. Ltd., Thailand. Cassava starch was purchased from E.T.C. International Co., Ltd., Thailand. High-purity OSA was purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). The other chemicals used in the study were of analytical grade.

**Preparation of OS cassava starch/OS rice flour:** Cassava starch or rice flour (35 g, dwb) was suspended in distilled water (65 g) with agitation. The pH of the suspension was adjusted to 8.5 using a 3% NaOH solution. Three percent OSA (based on dwb of starch) was added slowly to end within 1 h, while maintaining the pH at 8.5 and temperature at 35 °C. The reaction was continued for 2 h. After reaction, the pH was adjusted to 6.5 with 3% HCl solution. The slurry was then filtered, washed with water and air dried. Degree of substitution (DS) was determined by a titration method.\(^15\)

**Pasting properties:** The pasting properties of slurries (6% w/w for cassava starch and 8% w/w for rice flour) were determined by a Rapid Visco Analyzer (RVA-3D, Newport Scientific, Narrabeen, Australia) with a paddle rotated at a fixed speed of 160 rpm. The slurries were heated from 50 °C to 95.5 °C at the rate of 12 °C/min, maintained at 95.5 °C for 6 min, and then cooled to 50°C at the same rate.

**Noodle Preparation:** Rice flour was mixed with OS cassava starch (OCS, DS \( \approx 0.017 \)) or OS rice flour (ORF, DS \( \approx 0.009 \)), at 10, 20 and 30% (w/w). The mixed flour was suspended in water to obtain the slurry at 40% (w/w). Twenty six milliliter of slurry was poured into a 11× 22 cm stainless steel tray and steamed for 1 min. The sheet was removed from the tray and dried at 70 °C for 10 min. The noodle sheets were stacked, covered with cheesecloth and rested for 3 h at room temperature and then cut to 3 mm in width small strips. The noodles were further dried in a hot air oven at 40 °C until the moisture content decreased to 10-12%.

**Cooking quality:** Cooking time of dried noodle was determined following the AACC Approved method 16-50.\(^16\) Ten-gram noodles were cut into 5 cm length and boiled in 300 ml of distilled water in a beaker covered with a watch glass. Optimal cooking time was the time required for the opaque central core of the noodle to disappear when squeezed gently between glass plates for every 30 s. Cooking loss and cooking weight were determined by the AACC Approved Method 16-50.\(^16\) Noodles (10 g) were cooked to optimum time in 300 ml of distilled water. The cooked noodles were filtered through a stainless steel screen, rinsed with 20 ml distilled water and drained for 15 min before being weighed immediately. Solids content in the water was determined by drying at 105 °C for 24 h. The cooking loss and cooking weight were calculated with the following equations:
Cooking weight (\( \% \), g/100g dry noodle) = \( \frac{W_1 \times 100}{W_i \times D_M} \)

Cooking loss (\( \% \), g/100g dry noodle) = \( \frac{W_2 \times 100}{W_i \times D_M} \)

Where

- \( W_1 \) is the weight of the noodle sample after boiling (g)
- \( W_2 \) is the constant weight of water solid after drying in the oven (g)
- \( W_i \) is the weight of noodle sample (g)
- \( D_M \) is the dry matter content in the noodle (\%)  

Texture measurement: Textural qualities [tensile stress and elongation of the cooked noodles were measured by a EZ test texture analyzer (model EZ-S50N, Shimadzu Corporation, Japan) with noodle tensile jig and trapezium 2 software. Noodles (15 strips, 10 cm in length) were cooked to each its optimum time. The ends of noodle strips were clamped with noodle tensile jig with a distance between the grips of 4 cm. For each treatment, fifteen noodle strands the noodles were tested at a test speed of 1 mm/min using a 5 kg load cell, and the result of each sample was an average of fifteen measurements.

In vitro starch digestibility: Resistant starch content was determined according to the method of Englyst, et al.\(^3\) with some modifications. Cut noodle (0.1 g, 1x3x0.65 mm in size) was cooked to its optimum time. The cooked sample was incubated with pancreatic \( \alpha \)-amylase (4.5 ml, 200 U/ml) and amyloglucosidase (0.5 ml, 15 U/ml) in a water bath shaker with a shaking speed of 250 rpm for 20 min and then boiled for 10 min to stop reaction. Glucose concentration in the supernatant was measured using AACC method 76.13 (2000)\(^{17}\) to calculate the content of rapidly digestible starch (RDS). Also, the glucose concentration after 120 min incubation was determined to obtain the content of slowly digestible starch (SDS). Then, the content of RS was calculated from the equation; \( RS = total\ starch - RDS - SDS \).

Results and discussion:

**Pasting Properties of OS cassava starch/OS rice flour:** Pasting profiles of native cassava starch and rice flour, and their OSA modified products are shown in Figure 1. The OS cassava starch and OS rice flour displayed higher paste viscosity, but lower pasting temperature than the native starch/flour. This indicated that the incorporated bulky octenylsuccinate groups disordered the granule internal structure, allowing granules to swell at lower temperature and swell to a greater degree as compared to native starch/flour. Thirathumthavorn and Charoenrein\(^{10}\) postulated that the enhancement in the viscosity of OSA starch is probably due to three possible reasons, that are the high swelling volume of OSA starch,\(^{9,18}\) hydrophobic interactions\(^{11,19}\) and amylose–OSA inclusion complex.\(^{11}\) For setback value, it was found that the OS cassava starch and OS rice flour had significantly higher setback values than the native starch/flour. Generally, the setback value is used to indicate the degree of starch retrogradation (reassociation of starch chains, mainly amylose, by H-bond). Increase in the setback value by OSA modification might be caused by other network formations such as hydrophobic chains association or amylose–OSA complex and neighboring amylopectin association.\(^{10,11}\)

**Cooking quality of rice noodles:** Cooking qualities of noodles made from 100% rice flour and rice flour mixed with OS cassava starch or OS rice flour at various levels are summarized in Table 1. Cooking time of all noodle samples was in a range of 3.50 - 4.00 min. The noodles containing the modified starch/flour (except 30% ORF) had significantly higher cooking weight (281.1-335.6%) than the control sample (271.1%). The cooking weight of noodles added with OS cassava starch tended to increase as the level of the modified starch increased, while that with OS rice flour was not affected by the amount of the modified flour. Increase in cooking weight of OS starch/flour added noodles was due to a high capability of the modified starch/flour to swell, thus facilitating water percolation into the noodles during cooking. Noodle prepared from 100% rice flour had a cooking loss value of 1.5%. Although the noodles incorporated with the modified starch and flour displayed statistically higher
cooking loss values than the control sample, the magnitude of difference (less than 1%) was negligible in practical aspects.

Figure1. RVA profiles of native cassava starch and rice flour, and their OSA modified products.

Table 1 Cooking qualities of noodles made from 100% rice flour and rice flour mixed with OS cassava starch or OS rice flour at various levels

<table>
<thead>
<tr>
<th>Noodle sample</th>
<th>Cooking time (min)</th>
<th>Cooking weight (% dwb)</th>
<th>Cooking loss (% dwb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice flour 100%</td>
<td>4.0</td>
<td>271.1 ± 4.1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.5 ± 0.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>OCS 10%</td>
<td>4.0</td>
<td>296.9 ± 7.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.1 ± 0.0&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>OCS 20%</td>
<td>3.5</td>
<td>321.4 ± 2.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.8 ± 0.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>OCS 30%</td>
<td>3.5</td>
<td>335.6 ± 7.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.7 ± 0.0&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>ORF 10%</td>
<td>4.0</td>
<td>281.1 ± 1.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.4 ± 0.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ORF 20%</td>
<td>4.0</td>
<td>286.5 ± 5.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.3 ± 0.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>ORF 30%</td>
<td>4.0</td>
<td>278.2 ± 5.4&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.3 ± 0.0&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values represent means of three replicates ± standard deviation. Within the same column, the values with the same superscript are not significantly different (determined by ANOVA and DMRT, p<0.05)

Textural properties of rice noodle: The results of textural parameters of the noodle samples are given in Table 2. All noodles incorporated with the modified starch/flour (8.3-9.3 gf/m<sup>2</sup>) exhibited a higher tensile stress than the 100% rice flour noodle (7.4 gf/m<sup>2</sup>). This was possibly due to interaction of the hydrophobic portion of proteins existing in rice flour with hydrophobic groups of the modified starch/flour, resulting in strengthening the network structure. Elongation values (defined as the ratio of extension to the original length of samples) of the noodles made from rice flour mixed with the modified starch/flour (60.1-92.1%) were also considerably higher than that of the control (54.8%). The elongation values increased as the added amounts of the modified starch/flour increased, but the effect was more pronounced in noodles added with the OS cassava starch (77.1-92.1%) than those with the OS rice flour (60.1-70.5%). The increase in elongation of noodles containing the modified starch/flour might be attributed to the viscous nature of the OS starch/flour. The more pronounced effect of OS cassava starch would be a result of a sticky long paste characteristic of cassava starch.
Table 2: Textural parameters of the noodle samples

<table>
<thead>
<tr>
<th>Noodle sample</th>
<th>Tensile stress (gf/m²)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice flour 100%</td>
<td>7.4 ± 0.8c</td>
<td>54.8 ± 3.7f</td>
</tr>
<tr>
<td>OCS 10%</td>
<td>8.8 ± 0.8ab</td>
<td>77.1 ± 4.8c</td>
</tr>
<tr>
<td>OCS 20%</td>
<td>8.4 ± 0.7b</td>
<td>86.6 ± 4.9b</td>
</tr>
<tr>
<td>OCS 30%</td>
<td>8.3 ± 1.2b</td>
<td>92.1 ± 6.7a</td>
</tr>
<tr>
<td>ORF 10%</td>
<td>8.3 ± 0.9h</td>
<td>60.1 ± 1.4e</td>
</tr>
<tr>
<td>ORF 20%</td>
<td>8.9 ± 0.5ab</td>
<td>67.5 ± 5.5d</td>
</tr>
<tr>
<td>ORF 30%</td>
<td>9.3 ± 1.0a</td>
<td>70.5 ± 5.3d</td>
</tr>
</tbody>
</table>

Values represent means of fifteen replicates ± standard deviation. Within the same column, the values with the same superscript are not significantly different (determined by ANOVA and DMRT, p<0.05)

In vitro starch digestibility: RDS, SDS and RS contents in noodle products are presented in Table 3. The noodles containing modified starch/flour (except 20% ORF) had significantly higher RS content (31.2-32.6%) than the control sample (28.8%). As reported by Juansang et al., cooked OS canna starch contained much higher RS content (45.3%) than the cooked native canna starch. Other studies also suggested that OS-normal maize, -waxy maize, -potato, and -tapioca starches could be used as functional dietary fibers because of their resistance to digestive enzymes, which would increase the content of RS. However, in this study the increase in RS content of noodles by OS cassava starch and OS rice flour was only in a range of 3-4%. In most cases, SDS content of the noodles containing modified starch/flour was lower than the control sample. This was likely due to the transformation of the SDS to RS. Finally, addition of the modified starch/flour resulted in an increase of RDS (except for ORF 20%). This could be attributed to the finding that the OS cassava starch and OS rice flour had considerably lower pasting temperature than the native rice flour (Fig. 1). Therefore, the gelatinization degree of the mixed flours would be higher, thus rendering the accessibility of the hydrolyzing enzymes to starch chains.

Table 3: RDS, SDS and RS contents in cooked rice noodles

<table>
<thead>
<tr>
<th>Noodle sample</th>
<th>RDS (%dwb)</th>
<th>SDS (%dwb)</th>
<th>RS (%dwb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice flour 100%</td>
<td>14.6 ± 0.4d</td>
<td>35.5 ± 0.2a</td>
<td>28.8 ± 1.7b</td>
</tr>
<tr>
<td>OCS 10%</td>
<td>16.4 ± 0.9c</td>
<td>29.8 ± 0.5b</td>
<td>31.9 ± 0.9a</td>
</tr>
<tr>
<td>OCS 20%</td>
<td>18.9 ± 0.8a</td>
<td>27.7 ± 1.4ed</td>
<td>31.2 ± 0.8a</td>
</tr>
<tr>
<td>OCS 30%</td>
<td>18.6 ± 1.3ab</td>
<td>28.0 ± 0.9ed</td>
<td>32.6 ± 0.6a</td>
</tr>
<tr>
<td>ORF 10%</td>
<td>16.6 ± 0.6c</td>
<td>29.1 ± 0.6bc</td>
<td>31.8 ± 1.5a</td>
</tr>
<tr>
<td>ORF 20%</td>
<td>13.2 ± 0.9e</td>
<td>35.3 ± 1.2a</td>
<td>28.5 ± 0.5b</td>
</tr>
<tr>
<td>ORF 30%</td>
<td>17.3 ± 0.3bc</td>
<td>27.1 ± 0.8d</td>
<td>31.5 ± 0.7a</td>
</tr>
</tbody>
</table>

Values represent means of three replicates ± standard deviation. Within the same column, the values with the same superscript are not significantly different (determined by ANOVA and DMRT, p<0.05)
**Conclusion:** Partial replacement of rice flour with OS cassava starch and OS rice flour at 10 to 30% (w/w) provided noodles with higher cooking qualities and greater textural properties as compared with noodle from pure rice flour. RS content of the noodles with modified products was about 3-4% higher than the control. The RS content would be increased if more proportion of OS starch/flour is used. Their sensory evaluations are under investigation.

**References:**
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**Keywords:** Rice noodle, Resistant starch, Octenyl succinic anhydride, Cassava starch, Rice flour