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Research Article

Effect of soaking conditions on physicochemical properties and sensory quality of cooked glutinous rice with an electric rice cooker

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Abstract This research aimed to investigate the changes in physicochemical properties and sensory qualities of cooked glutinous rice (RD6) by using the electric rice cooker method with different soaking conditions compared to cooking glutinous rice by steaming in a conventional steamer (control). Glutinous rice grain was soaked at different soaking conditions of temperatures at 25 and 45℃ and soaking time for 30, 60, and 90 min, and then were cooked by the electric rice cooker. The results indicated that the degree of starch gelatinization was increasingly correlated with the moisture content and water activity of the cooked waxy rice. Moreover, with the increase in the degree of gelatinization, the hardness value exhibited a decreasing trend, and the adhesiveness value increased. The L* (lightness), a* (redness), and whiteness index of cooked glutinous rice increased when the temperature and time of soaking increased, while the color intensity decreased. The overall acceptability scores indicated that the lower soaking time obtained a higher score for cooked glutinous rice. Compared with the control sample, the soaking conditions for the temperature and time of 25℃/30 min or 45℃/30 min are viewed as a suitable ratio of a good quality product for cooked glutinous rice by using the electric rice cooker method, in which rice cooking provided the high score of overall acceptability on consumer preference.

Keywords glutinous rice, soaking temperature, soaking time, degree of gelatinization

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1. Introduction

The glutinous rice (*Oryza sativa* var. *glutinosa*) cultivar (or waxy rice) is dispersedly implanted in Southeast Asia. The glutinous rice in Thailand has major quantities, which are consumed as the standpoint food for daily cuisines in the northeastern and northern parts of the country. Both districts are the primary cultivating source of glutinous rice (Keeratipibul et al., 2008). Glutinous rice, called waxy rice or sticky rice, is characterized by high amylopectin or very low amylose content (<5%) but high in amylopectin, opaque appearance, soft texture, and resistance to retrogradation (Wang et al., 2021; Wang et al., 2022).

Glutinous rice cannot be cooked the same way as non-glutinous rice because heating in excess water results in a product with a pasty and slimy texture (Chen et al., 2022; Li et al., 2016). Traditionally, Thai waxy rice is cooked by steaming using a bamboo basket, straining cloth, and earthenware steamer after overnight soaking. The long-standing soaking is desired to soften the kernel, simplifying water absorbed by the starch during cooking. Gently raised temperatures can lessen the soaking time; higher water uptake rates are related to higher temperatures (Hsu et al., 1983). Soaking is a necessary procedure to widespread water inside rice grains and improves cooked rice's palatability (Tian et al., 2014). Soaking rice at ambient temperatures is commonly carried out, yet the extended time is desired to reach about 30 g/100 g wb of moisture content. Hot- or warm-water soaking is a general procedure to lessen soaking time because the enhancing temperature increases the hydration rate (Chakkaravarthi et al., 2008; Han et al., 2009).

At present, although quick-cooked rice has been distributed in the markets, quick-cooked waxy rice is still not available on the market. The important reason for the commercial obstacle of quick-cooked sticky rice could be due to the inconvenience in preparation and cooking during production. However, modern household cooking rice generally uses an electric rice cooker. This equipment is inexpensive and beneficial because it is convenient, expeditious, and efficient, and the rice is always available warm. Moreover, there were very few published articles that examined the impact of using an electric rice cooker on the quality of cooked glutinous rice. This study aims to investigate the effects of the soaking conditions, including time and temperature, on the physicochemical properties and organoleptic qualities of glutinous rice cooked by the electric rice cooker.

2. Materials and methods

2.1. Material

Glutinous rice samples, a variety of RD6 reported to have low amylose content (2% to 6%) used in this experiment, were harvested in 2022 in the northern part of Thailand in Phayao Province. The dehulled rice was stored in a refrigerator at a temperature of 5±1℃. The average moisture content of rice grain was about to 12.15±0.09% (wb).

2.2. Cooking rice by using an electric rice cooker

Glutinous rice as RD6 rice grains by different soaking conditions was used for preparation in the excess soaking water. The glutinous rice was soaked at a ratio of waxy rice and water of 1:1.5(w/w). The soaking temperature of rice grain was controlled at 25 and 45℃ during soaking by water bath (WNE10, Memmert, Germany), and the soaking time was carried out for 30, 60, and 90 min (Table 1). Then, the soaked glutinous rice grain was infused in the cooking pot and cooked until the electric rice cooker (KS-COM18, Sharp, Sakai, Japan) was turned off automatically and simmered for about 5 min to achieve wholly cooked rice. The cooked rice was used for physicochemical measurement and sensory evaluation.

2.3. Cooking rice by steaming in a conventional steamer

Rice (RD6) was soaked overnight in excess water at ambient temperature (Table 1). The soaked rice was then steamed using a conventional cooking container (holder) and steamer (pot) at atmospheric pressure. The grains were placed in a cylinder woven bamboo holder that fitted the top of the pot and vessel for generating the steam. Four hundred grams of soaked rice was filled in the holder, and excess water was provided to drain for 1 min before the holder was placed on top of the pot. A lid then covered the bamboo holder. The pot was heated on a gas kitchen stove, and steam percolated through the bed of rice until completely cooked rice (control).

Table 1. Parameter of cooked glutinous rice by electric cooker under different soaking conditions

Sample	Treatment	Soaking temperature (℃)	Soaking time (min)
Glutinous rice by steaming in a conventional steamer	Control	Room temperature	Overnight
Glutinous rice with the rice-to-water ratio of 1:1.5 (w/w) by cooking in electric rice cooker	25℃/30 min	25	30
	25℃/60 min	25	60
	25℃/90 min	25	90
	45℃/30 min	45	30
	45℃/60 min	45	60
	45℃/90 min	45	90

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2.4. Physicochemical properties

2.4.1. Moisture content analysis

Moisture content was measured using the oven drying method (AOAC, 2010). The waxy rice sample was heated in a hot air oven (UFE500, Memmert, Germany) at 105±2°C until constant weight. The moisture content was determined from the weight difference between the original dried samples and expressed on a wet-weight basis.

2.4.2. Water activity measurement

The water activity (a_w) of each cooked rice sample (about 2.0 g) was determined by using a water activity meter (Aqualab, Series 4TE, Pullman, WA, USA) following the method of AOAC (2010). The reading was taken approximately 60-90 sec.

2.4.3. Texture analysis

A texture analyzer (TA.XT. Plus, Stable Micro System, Godalming, UK) was used to investigate the texture of cooked rice kernel using a back extrusion test (Ghasemi et al., 2009). A 20 g sample of cooked grain was infused inside the test cylinder of 6 cm diameter and pressed with a 150 g weight for 30 sec before conducting the actual test. During the measurement, the cooked rice sample in the cylindrical test cell was compressed by a cylindrical plate plunger of 35 mm diameter. The pre-test speed, test speed, and post-test speed of the plunger were set at 1.0, 1.0, and 10 mm/sec, respectively. The compression distance was 50% strain. A force–time curve was obtained from the test. The following textural parameters were determined: hardness–the maximum compressive force during extrusion (N), adhesiveness–area under the curve (N.s), which is expressed as a negative value. The instrument software derived other texture parameters of springiness, cohesiveness, gumminess, chewiness, and resilience.

2.4.4. Color measurement

The color values of cooked rice were measured utilizing a HunterLab colorimeter (HunterLab, ColorQuest XE, Reston, Virginia, USA). Measurement was based on the CIE system of color values of L* (lightness), a* (redness) and b* (yellowness) (Lee et al., 2001). The measurement was carried out in triplicate. Furthermore, the whiteness index (*WI*) was calculated as follows:

$$WI = 100 - \left[\sqrt{(100-L^*)^2 + (a^*)^2 + (b^*)^2}\right] \quad (1)$$

The color intensity value (*B*) of cooked rice kernel was calculated using the following formula (Islam et al., 2002):

$$B = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

2.4.5. Measurement of gelatinization degree

The degree of starch gelatinization was measured using some modified methods by Birch and Priestley (1973) and Guraya and Toledo (1993). The cooked rice was dried in an oven at 55℃ and ground through the sieve (80 mesh). The sample (0.2 g) was prepared in 125 ml Erlenmeyer flasks, and 100 mL of distilled water was added. A 2.0 mL 10 M KOH was mixed for 5 minutes before centrifugation at 2,500 rpm for 20 min. The supernatant (1.0 mL) was pipetted and added with 0.4 mL 0.5 M HCl, followed by 10 mL of distilled water and 0.1 mL of iodine solution. The mixture was homogenized then measuring the absorbance at 600 nm. The degree of gelatinization of standard starch was prepared in the same manner of the sample to obtain the standard curve of rice and applied to determine the degree of gelatinization of the sample.

2.5. Sensory evaluation

This study was approved by the University of Phayao Human Ethics Committee (Study No. UP-HEC 1.2/042/66). Sensory quality examination of the cooked waxy rice was performed with the help of forty untrained panelists (19 to 42 years old) who received a portion of 15 g of cooked rice samples of each treatment. The samples were presented to the panelists on glass plates where all the samples were served warm, and each sample was coded with a random three-digit number. Hedonic ratings using a 9-point scale (with 1=dislike extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like slightly; 7=like moderately; 8=like very much; 9=liked extremely) were adopted to determine the sensory quality. Panelists were required to evaluate the cooked rice based on its appearance, color, flavor, texture, and overall acceptability.

2.6. Statistical analysis

The data obtained from the control and treatments was presented as mean±SD. IBM SPSS Statistic 27.0 software was used for the statistical analysis by one-way ANOVA. Duncan's new multiple range test was performed for significance among each sample ($p<0.05$).

3. Results and discussion

3.1. Moisture content and water activity

The moisture contents of cooking rice by electric rice cooker with the variation of temperature and time of soaking, compared to steaming cook rice (control) are shown in Table 2. The highest moisture content (61.54±1.78% wb) of cooked waxy rice occurred at the soaking temperature of 25℃ for 90 min (25℃/90 min). In contrast, the lowest moisture content (49.86±1.13% wb) was found in the control sample. The soaking temperature and time had a significant effect ($p<0.05$) on the moisture content of cooked rice.

The moisture content of glutinous rice samples has an effect on starch gelatinization during the cooking process of the cooked rice. Suppose glutinous rice kernel is not sufficiently moistened in the interior. In that case, the starch in the internal of the rice may not be completely gelatinized by heating, resulting in cooked rice with a starchy texture (Taghinezhad et al., 2016). The result demonstrates that the water absorption will increase with soaking time and then drop in the maximum assimilation capacity (Bello et al., 2007). The higher temperature increases the moisture content due to the hot temperature provoking the opening of grain pores, and then more water enters the rice endosperms. Miah et al. (2002) explained that by increasing the time or temperature of soaking, the water absorption would increase for the ideal water level. The result demonstrated that the moisture content of cooked glutinous rice tended to increase with the degree of starch gelatinization. During the cooking process, the water in the rice kernel affects the swelling of starch granules. The heating temperature setting for the electric rice cooker was used to accelerate the process of heating water, reaching the boiling point of water (100℃). Water absorption by cooked grains increased with the increased water content (Thupeeban and Kannan, 2017). Several studies reported varying amounts of moisture content after cooking (≥30%) required for the gelatinization of starch depending on the soaking conditions, such as temperature or time of soaking (Ding et al., 2019; Fu et al., 2013; Guo et al., 2018; Nawaz et al., 2016).

The water activity (a_w) of cooked glutinous rice was significantly affected at different temperatures and times of soaking (Table 2). The water activity of cooked rice increased with the increase of soaking time. No significant differences ($p>0.05$) were found in the water activity of the cooked waxy rice for 25℃/60 min, 25℃/90 min, 45℃/60 min 45℃/90 min. Specifically, the water activity in the 25℃/30 min and 45℃/30 min was lower than that of those conditions. However, the water activity of cooked waxy rice with different temperatures and times in all soaking conditions was significantly higher ($p<0.05$) than the control sample.

Table 2. Moisture content and water activity of cooked glutinous rice by electric cooker under different soaking conditions

Soaking conditions	Moisture content (%)	Water activity
Control[1)]	49.86±1.13[2)c]	0.988±0.001[c]
25℃/30 min	58.37±0.88[b]	0.996±0.004[b]
25℃/60 min	59.11±1.32[b]	0.998±0.005[a]
25℃/90 min	61.54±1.78[a]	0.998±0.001[a]
45℃/30 min	58.67±0.47[b]	0.996±0.000[b]
45℃/60 min	59.03±1.62[b]	0.997±0.002[ab]
45℃/90 min	60.76±0.94[a]	0.998±0.001[a]

[1)]Control refers to cooking of glutinous rice by steaming it in a conventional steamer.
[2)]Mean±SD (n=3) and different superscript letters ([a-c]) indicate significant differences ($p<0.05$).

3.2. Texture properties of glutinous cooked rice

The textural parameters of cooked glutinous rice by textural profile analysis (TPA) are presented in Table 3. The temperature and time of soaking affected the hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience of cooked glutinous rice. Texture mainly indicated the hardness of cooked waxy rice. At the variation of temperature and time of soaking, the hardness of cooked glutinous rice decreased significantly ($p<0.05$) as the temperature and time in soaking increased. As shown in Table 2, the hardness of 25℃/30 min cooked waxy rice was slightly lower than that of the control sample, but the difference was not statistically significant ($p>0.05$). However, no significant differences were found in the hardness value of cooked waxy rice between the 25℃/60 min and 25℃/90 min and between the 45℃/60 min and 45℃/90 min.

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Table 3. Textural profile analysis (TPA) of cooked glutinous rice samples by electric cooker under different soaking conditions

Soaking conditions	Hardness (N)	Adhesiveness (g · sec)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
Control[1)]	585.42±71.44[2)a]	-35.81±9.09[d]	0.87±0.06[a]	1.36±0.04[a]	273.46±21.47[a]	96.88±17.30[a]	0.85±0.07[a]
25°C/30 min	577.75±35.18[ab]	-34.29±8.71[cd]	0.85±0.04[a]	1.33±0.03[a]	269.05±18.22[a]	93.43±14.43[a]	0.84±0.02[a]
25°C/60 min	529.50±24.26[c]	-31.46±2.64[b]	0.78±0.01[b]	1.22±0.05[b]	246.58±8.96[b]	85.65±6.84[b]	0.80±0.08[b]
25°C/90 min	519.48±64.46[cd]	-29.94±5.72[ab]	0.76±0.03[b]	1.19±0.04[bc]	240.06±12.67[bc]	83.38±2.53[b]	0.77±0.04[b]
45°C/30 min	570.26±53.78[b]	-33.69±2.78[c]	0.84±0.14[a]	1.31±0.06[a]	265.56±18.94[a]	92.23±11.16[a]	0.83±0.09[a]
45°C/60 min	511.37±63.42[de]	-29.08±4.63[a]	0.75±0.16[bc]	1.18±0.03[bc]	238.14±5.83[c]	82.72±12.15[b]	0.75±0.12[bc]
45°C/90 min	506.02±45.64[e]	-28.87±3.71[a]	0.74±0.08[c]	1.16±0.02[c]	235.65±11.25[c]	81.86±8.46[b]	0.73±0.05[c]

[1)]Control refers to cooking of glutinous rice by steaming it in a conventional steamer.
[2)]Mean±SD (n=3) and different superscript letters ([a-d]) in the same column indicate significant differences ($p<0.05$).

Among various physical properties, hardness is the most frequently tested parameter for cooked rice. Physically, the hardness of cooked rice is defined as the ability of cooked rice to withstand a certain load over a given period of time (Eliasson and Tatham, 2001). During soaking, the glutinous rice granules absorbed water and swelled greatly compared to their original size. The grain expansion caused ruptures of the rice kernel and, consequently, little amylose in glutinous rice leaching. Demonstration of amylose leaching in the residence of water above the gelatinization temperature is well-indicated (Leelayuthsoontorn and Thipayarat, 2006; Tester and Morrison, 1990). Furthermore, amylopectin in glutinous rice of lower molecular weight may be extracted (Hizukuri, 1996). Apparently, the higher temperature and time of soaking condition appear to decrease the hardness of cooked glutinous rice. The shorter temperature and time yielded a higher hardness in texture, which may be because the soaking water in the rice grain was not enough for the starch gelatinization to take place wholly. Generally, the minimum water content required for gelatinization of rice starch is the ratio of rice: water as 1:1 (Ramesh et al., 2000). Similarly, several factors, such as temperature, time, and stirring in a process, affect the eating quality of cooked rice, all of which have affected the hardness and other cooking characteristics of cooked rice. (Bemiller, 2018).

Another significant regard to rice quality, adhesiveness or stickiness was involved. The temperature and time of soaking in cooked glutinous rice of 25°C/30 min and control sample did not show significant differences ($p>0.05$) with lower adhesiveness compared to 25°C/60 min, 25°C/90 min, 45°C/30 min, 45°C/60 min and 45°C/90 min (Table 3). Moreover, the adhesiveness of cooked waxy rice at 25°C/90 min was not significantly different from the 45°C/60 min and 45°C/90 min.

Regarding rice quality, rice adhesiveness is also a significant characteristic for estimating eating quality (Li et al., 2020), i.e., non-waxy rice is less sticky, while waxy rice is always sticky. During grain soaking, the amylopectin and amylose leached out from the interior and were likely to induce the adhesiveness characteristic of cooked glutinous rice (Ramesh et al., 2000). Adhesiveness is associated with the amount of starch and gelatinization of starch. Our results show that soaking conditions with lower temperature and time produced cooked glutinous rice with a slight stickiness.

3.3. Color

Table 4 shows L* (lightness), a* (red to green), and b* (yellow to blue) of glutinous cooked rice at the variation of temperatures and times of soaking. Our results indicate that the lightness and the color values were dependent on the soaking conditions with different temperatures and times of soaking. Higher temperature and time of soaking decreased the lightness and redness of cooked glutinous rice, as shown in L* and a* values, respectively. This indicates that lower soaking in temperature and time could provide a more fabulous lightness product. However, significant differences ($p<0.05$) were observed in cooked waxy rice with an electric cooker for the L* value in all soaking conditions compared to the control. The high lightness value of rice demonstrated that the color of rice was brighter. The lowest L* values were found in the cooked rice for the control sample. Although the redness of the 25°C/30 min was highest for this study, yet no

Table 4. Color parameters of cooked glutinous rice by electric cooker under different soaking conditions

Soaking conditions	Color parameters			Whiteness index	Color intensity value
	L*	a*	b*		
Control[1)]	76.30±2.11[2)c]	-0.73±0.15[a]	13.03±0.60[a]	72.94±2.05[c]	13.03±0.40[a]
25℃/30 min	92.73±1.70[a]	-0.67±0.25[a]	6.77±0.55[d]	90.04±1.41[a]	6.80±0.61[d]
25℃/60 min	89.13±1.23[a]	-1.00±0.10[b]	8.07±0.38[c]	87.42±1.32[a]	8.13±0.45[c]
25℃/90 min	84.37±0.51[b]	-1.27±0.31[bc]	8.57±1.19[b]	82.13±0.61[b]	8.66±0.97[b]
45℃/30 min	88.10±2.07[a]	-1.53±0.31[cd]	7.60±1.23[c]	85.80±2.20[a]	7.75±1.08[c]
45℃/60 min	82.33±1.63[b]	-1.80±0.35[d]	8.87±0.23[b]	80.15±1.51[b]	9.05±0.52[b]
45℃/90 min	80.43±0.31[b]	-1.90±0.44[d]	9.23±0.25[b]	78.28±0.26[b]	9.42±0.36[b]

[1)]Control refers cooking glutinous rice by steaming it in a conventional steamer.
[2)]Mean±SD (n=3) and different superscript letters ([a-d]) in the same column indicate significant differences ($p<0.05$).

significant difference ($p>0.05$) from the control. The yellowness (b*) of cooked glutinous rice increased significantly with the temperature and time of soaking.

Based on the results of a color change, the degree of color change depended on the temperature and time of soaking, heating, and soaking water content, but the main cause of color change occurred during cooking (Hapsari et al., 2016). Higher temperature and time during soaking produced cooked rice with a darker color (L*) but more decreased redness (a*) and yellowness (b*) compared to those of the lower temperature and time in soaking conditions. Yellowness was regularly predominantly increased if rice was obtained for a greater temperature and time of soaking.

3.4. Whiteness index

The temperature and time of soaking conditions affected the whiteness index of cooked waxy rice. The highest whiteness index (90.04±1.41) was found in cooked rice with a soaking temperature of 25℃ for 30 min (25℃/30 min), while the lowest whiteness index (72.94±2.05) was found in cooked rice with steaming in a conventional steamer (control). The results indicate that the whiteness index of cooked waxy rice decreased with the temperature increase and soaking time (Table 4).

The whiteness index of cooked glutinous rice negatively affects consumer's acceptability and results in a loss in market value (Bhattacharya, 2004). Glutinous cooked rice grains have decreased the degree of whiteness as the temperature and time of soaking increased. A significant difference was found for the whiteness of cooked rice in all soaking conditions and control. The soaking temperature and time were distinctly an essential factor affecting the degree of whiteness. Higher temperature and time cause lower value of whiteness. These findings are in accordance with a study by Leelayuthsoontorn and Thipayarat (2006), who reported that the darkening of the cooked rice kernel was attended by the evolution of a more noticeable yellow color.

3.5. Color intensity value

Table 4 shows the effect of soaking conditions with different times and temperatures on the color intensity value for cooked waxy rice. This value increased with an increase in time and temperature of soaking. However, the cooked rice control sample presented a high-intensity value. In addition, a significant difference ($p<0.05$) was observed in cooked waxy rice for the color intensity value in the control sample compared to cooked waxy rice in all soaking conditions of the cooking rice cooker. This study indicated that the soaking temperature has a greater effect on the color intensity value than the soaking time. However, no significant differences ($p>0.05$) were found in color intensity value of cooked waxy rice for 25℃/90 min, 45℃/60 min, and 45℃/90 min.

Discoloration of rice due to the soaking of the rice grain is one of the major quality indicators. This change is a negative effect of the soaking process since dark-colored cooked rice loses market value and lowers consumer acceptance in many countries (Bhattacharya, 2004). The cooked waxy rice was measured for the color intensity value since soaking conditions at different temperatures and times indicated that discoloration was largely caused by a non-

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enzymatic browning reaction with the Maillard type (Islam et al., 2002). Thus, the soaking conditions affect the change of the color intensity in cooking glutinous rice with an electric rice cooker.

3.6. Degree of gelatinization

The variation of temperature and soaking time affected the degree of starch gelatinization, as shown in Fig. 1. The mean values of the degree of gelatinization of cooked glutinous rice in all soaking conditions of the cooking rice cooker and control sample ranged from 89.99±0.89% to 93.97±0.65%. The degree of gelatinization of cooked rice tended to increase with increasing the soaking temperature and time. All soaking conditions of the cooking rice cooker resulted in a greater increase in the degree of gelatinization ($p<0.05$) compared to the control sample. No significant difference ($p>0.05$) was found for the degree of gelatinization of cooked waxy rice at the soaking conditions of 25℃/60 min, 25℃/90 min, and 45℃/30 min, while the higher value was obtained in 45℃/60 and 45℃/90 min.

The degree of starch gelatinization is another major thermal property of rice (Guo et al., 2018). Starch gelatinization is a phenomenon that breaks down the intermolecular bonds of starch molecules in the possession of heat and water, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to prefer more water. Water permeability will increase randomly in the normal structure and decrease the size and number of crystalline regions (Guo et al., 2018).

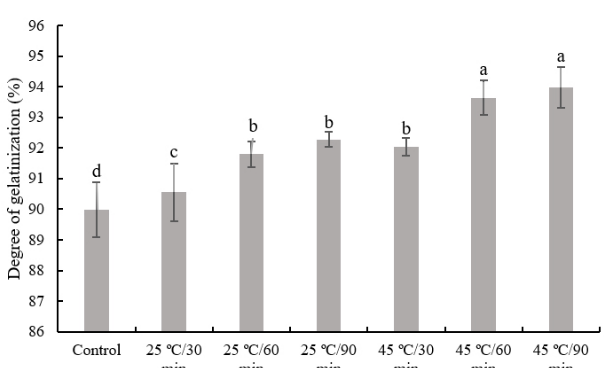

Fig. 1. Degree of starch gelatinization of cooked glutinous rice by electric cooker under different soaking conditions. Control refers to cooking glutinous rice by steaming it in a conventional steamer. Mean±SD (n=3) and different superscript letters ([a-d]) on the bars indicate significant differences ($p<0.05$).

Crystalline regions do not allow water entry, yet heat causes such regions to be diffused. Therefore, the chains begin to separate into an amorphous form (Bemiller, 2018). Thus, gelatinization requires enough of water. In addition, greater water penetration occurs during cooking, increasing the degree of starch gelatinization (Saif et al., 2004). The increment in the degree of gelatinization could be relayed to the weakness of the starch to amylase and, therefore, the extent rate of starch digestibility and glycemic index. The obtained results of the degree of gelatinization are in conformity with Hapsari et al. (2016) who studied the swelling of starch granules since water absorption by the rice grains during soaking. Soaking at ambient temperature is quite slow, whereas hot soaking requires certain control due to a moisture gradient enhanced at high precipitous temperatures and may cause sloughing-off of the surfaces before hydration to the grain core is accomplished (Bhattacharya, 2004). Thus, warm- or hot-water soaking is a way to increase the moisture content of rice and gelatinize the starch in a shorter time (Han et al., 2009).

3.7. Sensory qualities

A summary of the data obtained from the organoleptic test is given in Table 5. The mean scores of appearance, color, flavor, texture, and overall acceptance of cooked glutinous rice were evaluated by a 9-point hedonic scale. Cooked waxy rice at 25℃/30 min, 45℃/30 min, and the control sample received a higher score for texture and overall liking than 25℃/60 min, 25℃/90 min, 45℃/60 min, and 45℃/90 min. Although the mean scores of the appearance attribute showed significant differences ($p<0.05$) between the control sample and other soaking conditions for cooking rice cookers, there was no significant difference ($p>0.05$) from 45℃/90 min compared to the control. In addition, the results showed that the cooked glutinous rice with the 25℃/30 min gave the higher score of flavor (7.20±1.07 out of 9) among all soaking conditions, while the higher score of color was obtained from the control sample (6.93±0.07 out of 9).

3.8. Correlations between degree of gelatinization, physicochemical properties, and organoleptic quality

In the present study, we found that physiochemical properties such as moisture content, water activity, hardness, and adhesiveness showed a high positive or negative correlation

Table 5. Sensory evaluation (Hedonic test) of cooked glutinous rice by electric cooker under different soaking conditions

Soaking conditions	Appearance	Color	Flavour	Texture	Overall acceptance
Control[1)]	6.67±1.05[2)c]	6.93±0.70[a]	6.07±0.88[d]	6.40±0.99[ab]	6.60±0.74[ab]
25°C/30 min	7.20±1.37[b]	6.40±1.44[c]	7.00±0.93[a]	6.47±1.30[a]	6.73±0.77[a]
25°C/60 min	7.13±1.19[b]	6.07±1.41[d]	6.60±1.45[b]	6.33±1.29[b]	6.53±1.06[b]
25°C/90 min	7.07±1.28[b]	6.13±1.13[c]	6.47±0.99[c]	5.93±1.53[c]	6.27±1.03[c]
45°C/30 min	7.47±1.06[a]	6.73±0.59[b]	6.67±1.23[b]	6.43±1.24[a]	6.67±1.18[a]
45°C/60 min	7.07±0.80[b]	6.67±0.62[b]	6.27±1.03[cd]	5.80±1.26[c]	6.33±0.98[c]
45°C/90 min	6.80±0.98[c]	6.40±0.91[c]	6.13±1.46[d]	5.67±1.11[cd]	5.87±0.92[d]

[1)]Control refers to cooking of glutinous rice by steaming it in a conventional steamer.
[2)]Mean±SD (n=3) and different superscript letters ([a-d]) in the same column indicate significant differences ($p<0.05$).

with the degree of starch gelatinization due to the variation of temperature and time of soaking. As shown in Fig. 2, a significantly negative correlation existed between the hardness of cooked glutinous rice. On the other hand, the moisture content, water activity, and adhesiveness of cooked rice also showed a positive correlation with the degree of gelatinization (Fig. 2). The adhesiveness of cooked waxy rice had a significantly negative correlation with the texture score, while the hardness had a significantly positive correlation (Fig. 2). Additionally, the score of overall acceptance of cooked glutinous rice had a highly positive correlation with texture score.

The hardness present in samples increased with a decrease in the degree of gelatinization. Once cooked, the structure of the gelatinized starch granule would be able to absorb more water than a starch that had not been gelatinized (Jaiboon et al., 2011; Rattanamechaiskul et al., 2017). Therefore, the hardness value decreases while the adhesiveness increases with a higher degree of starch gelatinization. It indicates that increasing the degree of starch gelatinization would contribute to the texture of the cooked waxy rice being tender and sticky.

In this study, the degree of starch gelatinization of cooked glutinous rice showed the highest correlation coefficient with

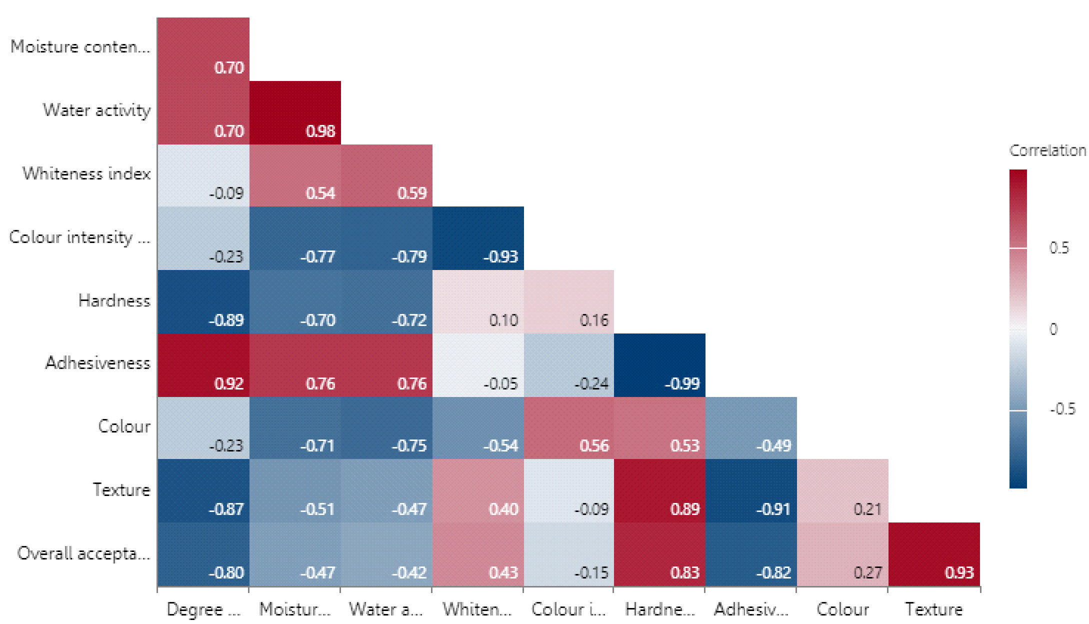

Fig. 2. Correlation between the degree of starch gelatinization and some physicochemical organoleptic properties.

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the adhesiveness (r=0.92) and hardness (r=-0.89), followed by texture score (r=-0.87) and overall acceptance score (r=-0.80) (Fig. 2). The hardness showed a high negative correlation (r=-0.99) with the adhesiveness of cooked rice. However, the increasing texture score might be attributable to the enhancement of overall acceptance.

According to the data obtained for sensory evaluation, the results of this study indicate that the lower score for appearance, color, texture, and flavor of cooked waxy rice with higher temperature and time in soaking affected the overall acceptance by the panelists. Adhesiveness to lips, hardness, springiness, cohesiveness, gumminess, chewiness, and resilience of mass and tooth pack demonstrated the water effect of the texture of cooked waxy rice. The result corresponds with the measured value with the textural profile analysis (TPA). Cooked glutinous rice odor, whiteness, stickiness, softness, and sweetness are an overall reference to the cooking quality, which consumers use as an index in arbitrating to purchase that type of rice (Zheng et al., 2021).

4. Conclusions

We investigated the effects of soaking conditions at various temperatures and times on the physicochemical properties and sensory quality of cooked glutinous rice using the electric rice cooker method, compared to cooked glutinous rice steaming in a conventional steamer (control sample). The degree of gelatinization in cooked waxy rice correlates positively with the moisture content and water activity. Higher temperatures and times of soaking result in a decrease in hardness and an increase in the adhesiveness of cooked glutinous rice. The degree of starch gelatinization strongly correlated with changes in hardness and adhesiveness values. Higher temperature and time in soaking increased the b* and color intensity value of cooked waxy rice, but it reduced the L* a* and whiteness index. From comparing the physicochemical properties and sensory qualities of cooked glutinous rice between the electric rice cooker method and control, the optimum soaking conditions for the temperature and time of 25℃/30 min or 45℃/30 min is considered to achieve consumer acceptability. The physicochemical properties and sensory qualities of cooked glutinous rice by the electric rice cooker method are similar to those of the control sample with these specific soaking conditions of 25℃/30 min or 45℃/30 min. The soaking temperature and time also affected the eating quality of cooked waxy rice. Therefore, rice cookers should consider this main point to obtain the benefit to consumers.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Khwanchai P, Fong-In S. Methodology: Khwanchai P, Phandaeng N. Formal analysis: Prommajak T. Validation: Khwanchai P. Writing - original draft: Khwanchai P. Writing - review & editing: Fong-In S, Prommajak T.

Ethics approval

This study was approved by the University of Phayao Human Ethics Committee (Study No. UP-HEC 1.2/042/66).

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