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Original article

Nipa palm (*Nypa fruticans*) Improves the Storage quality and antioxidant activity of rice cake (*Sulgidduk*)

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Abstract. This study investigated the properties of nipa palm powder, upon addition to the traditional Korean food *Sulgidduk*. The samples were designed as N0 (without nipa palm powder), N1 (with 1% nipa palm powder), N2 (with 2% nipa palm powder), N3 (with 3% nipa palm powder), and N4 (with 4% nipa palm powder). The moisture content of the *Sulgidduk* samples increased as the amount of nipa palm powder increased. No significant difference was observed in the pH between samples. The total polyphenol and flavonoid contents were observed to significantly increase in the *Sulgidduk* samples as the amount of nipa palm powder increased. The hardness, cohesiveness, and chewiness of the samples decreased as the amount of nipa palm powder increased; however, the brittleness increased. Although sensory evaluation revealed that the overall preference was the greatest for the N0 samples, the N2 samples had the strongest retarding retrogradation effect.

Keywords: antioxidant activity, nipa palm, texture analyze, retarding retrogradation, sensory evaluation

Introduction

Recently, the consumption of rice cakes has increased due to the current widespread preference of simple healthy meals in Korea (1). Therefore, it is necessary to develop a variety of rice cake types that provide health benefits and convenience to the consumer for promoting rice consumption (1,2).

Sulgidduk is the most popular Korean traditional steamed rice cake due to its simple method of preparation (3). However, as *Sulgidduk* is made of only non-glutinous rice, it lacks nutrients and easily retrogrades due to its chemical structure (4). Non-glutinous rice is composed of amylose which has helix form, because of their chemical structure they tightly binding each other so that they has rapid retrogradation rate, and amylopectin which has a slow retrogradation rate because of their high molecular wight and chemical structure (4).

Although rice starch is composed of 20% amylose and 80% amylopectin, the amount of amylose is not negligible as its smaller size means that in terms of the number of molecules, high amount of amylose is present compared to amylopectin (4). To overcome the rapid retrogradation of starch, many studies was conducted such as addition of modified starch (5), oligosaccharides (6), and polyphenols to reduce the amylose content or to develop amylose alternatives (7).

Nipa palm (*Nypa fruticans* Wurmb) belongs to the family Araceae (8). Nipa palm, which is widespread in Southeast Asia, the Philippines, the Ryukyu Islands, and Sarack, grows up to 1 m in length and thrives near estuaries, unlike coconut (*Cocos nucifera*) and oil palms (*Elaeis guineensis*) (10). As all parts of the nipa palm can be used as food, including the fronds, leaves, husks, and shells, so it holds high value as food resource (11,12). Its composition includes the following: low levels of starch and protein and high levels of polyphenol and inorganic compounds, such as Ca, P, and Mg (9). Additionally, nipa palm has been used to treat liver disease, tuberculosis, and tooth inflammation due to the high levels of polyphenol compounds, which act as antimicrobial antioxidative agents (11,12). Previous studies involving nipa palm have investigated its effect such as antioxidant activities and sensory preference for use in wine (15), vinegar (16), and soup (12). However, there is no previous study has investigated the use of nipa palm powder in *Sulgidduk*.

The purpose of this study was to confirm the effect of retarding retrogradation by reducing the amylose content by replacing amylose with nipa palm powder. Further, we investigated whether the high antioxidant content of nipa palm can result in increased antioxidant activities of *Sulgidduk* compared to the standard product.

Materials and Methods

Materials

Rice and nipa palm powder were prepared by pulverization using high speed grinder (CRT-04, Hungchuan Machinery Enterprise, Taipei, Taiwan), followed by passing through a 40-mesh sieve. Before pulverization, the rice (Uiseong, short grain, Korea) was washed five times and soaked in water for 24 h, then dried for 1 h at room temperature (25°C). Nipa palm (SSD Food Co., Ltd, Seoul, Korea) was washed five times and soaked in water for 5 h, then dried for 2 h at room temperature (25°C) using freeze dryer (FD8508, Ilshin Biobase Co. Ltd., Gyeonggi, Korea). Sugar (CJ Cheil jedang Co., Ltd, Incheon, Korea) and salt (CJ Cheil jedang Co., Ltd, Incheon, Korea) were preparation from the local market.

Preparation of Sulgidduk

The formula for *Sulgidduk* preparation was determined based on previous studies regarding the addition of radicchio (2) and the formula of *Sulgidduk* is shown in Table 1. Samples were prepared using different amounts of nipa palm powder and designated as N0 (without nipa palm powder), N1 (with 1% nipa palm powder based on rice powder), N2 (with 2% nipa palm powder based on rice powder), N3 (with 3% nipa palm powder based on rice powder), and N4 (with 4% nipa palm powder based on rice powder).

Before steaming the sample, each powder (rice and nipa palm) was mixed, and salt and sugar were added as per the formula provided in Table 1. The mixtures were steamed using a steamer (25×25×10 cm) for 20 min at 100°C. After steaming, the sample was cooled at room temperature (25°C) for 30 min before using it as test samples.

Antioxidant Activities of Nipa Palm

Preparation of sample

To extract each sample, the samples were freeze-dried for 96 h then pulverized using a high-speed grinder (CRT-04, Hungchuan Machinery Enterprise,

Table 1. Formulas for the preparation of *Sulgidduk* with different amounts of nipa palm powder

Ingredient (g)	Nipa palm powder content based on rice flour (%)				
	N 0%[1)]	N 1%	N 2%	N 3%	N 4%
Rice flour	500	495	490	485	480
Nipa palm powder	0	5	10	15	20
Water	50	50	50	50	50
Sugar	50	50	50	50	50
Salt	5	5	5	5	5

[1)]*Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.*

Taipei, Taiwan). An aliquot of 1 g sample was added to a 50 mL conical tube with 15 mL of distilled water. After mixing, the samples were extracted for 3 h using a water bath (BS-20, Jeio Tech, Seoul, Korea) at 80°C, 150 rpm. This mixture was then centrifuged for 10 min × 3,000 g using a centrifugal separator (Universal 32R, Hettich, Tuttlingen, Germany), and the samples were filtered through Whatman No. 1 filter paper.

Total phenol content

To analyze the total polyphenol content, a modified version of the Folin-Denis method suggested by Akay et al. (17). A solution containing 0.9 M Folin-Ciocalteu reagent (Junsei Chemistry, Tokyo, Japan) and 20% sodium carbonate (Na2Co3 4g/ distilled water 20 mL) (Merck kGaA, Darmstadt, Germany) was prepared, and samples (10 μL) were vortexed with distilled water (790 μL) for 1 min. A total of 50 μL of 0.9 N Folin-Ciocalteu reagent (Junsei Chemistry, Tokyo, Japan) was added to 150 μL of 20% sodium carbonate (Merck kGaA, Darmstadt, Germany), and the reaction mixture was incubated for 30 min at room temperature in darkness. The absorbance of each sample was measured at a wavelength of 750 nm using a microplate reader (Infinite 200 PRO, Tecan, Mannedorf, Switzerland). To prepare garlic acid standard, 0.008g of garlic acid and 4mL of distilled water was mixed then vortexed 1 min (Merck kGaA, Darmstadt, Germany). Garlic acid was used as a standard and the absorbance of each sample was converted to gallic acid equivalent (GAE).

Flavonoid content

The flavonoid content was measured using a slightly modified method from Oh et al. (18) with slight modifications. A total of 1 mL of sample was vortexed with 150 μL of 5% sodium nitrite (NaNO2 0.1g/ distilled water 1.9 mL) (Junsei Chemistry, Tokyo, Japan) for 6 min in darkness at room temperature (25°C), followed by addition of 300 μL of 10% aluminum chloride (AlCl3 0.4g/ distilled water 3.6mL) (Junsei Chemistry, Tokyo, Japan) and incubation in the dark for 5 min using at room temperature (25°C). The solution was reacted by adding 1 mL of 1 N sodium hydroxide (NaOH 2g/ distilled water 50 mL) (Daejung Chemicals & Metals, Gyeonggi, Korea), and the absorbance of each sample was measured at 520 nm. To prepare quercetin as standard, 0.008g quercetin and 40 mL of distilled water was mixed and vortexed 1 min. Absorbance calibration curves were prepared using quercetin (Sigma-Aldrich Co., Ltd, MO, USA) as a standard, and the total flavonoid content of each sample was converted to quercetin equivalent (QE).

Ferric-reducing antioxidant power (FRAP)

FRAP was measured following the methods of Kim et al. (19) with some modifications. The reagents used included 0.2 M phosphate buffer (pH 6.6), 1% potassium ferricyanide (K3[Fe(CN)6] 0.1g/ distilled water 10 mL) (Merck kGaA), 10% trichloroacetic acid (CCl3COOH 1g/ distilled water 10 mL) (Sigma-Aldrich Co., Ltd, MO, USA), and 0.1% ferric chloride (FeCl3 0.01g/ distilled water 10 mL) (Junsei Chemistry, Tokyo, Japan). A total of 250 μL of sample, 250 μL of 0.2 M phosphate buffer, and 1% potassium ferricyanide were allowed to react for 30 min at 50°C using fermentor(digital fermentor, Goldbread, Gyeonggi, Korea), and the mixture was treated with 250 μL of 10% trichloroacetic acid. A total of 0.5 mL of this mixture was treated with 0.5 mL of distilled water and 0.1% FeCl3. The absorbance of each solution was measured at 700 nm.

Quality Characteristics of *Sulgidduk*

Moisture content, pH, and color

To measure the moisture content, 5 g of the sample was obtained from the central part. The moisture content of each sample was measured using a moisture analyzer (MB35, OHAUS, Zurich, Switzerland).

Before measuring the pH value, 10 g of the sample was mixed with 90 mL of distilled water and homogenized (Unidrive 1000D, CAT M. Zipperer GmbH, Staufen, Germany) for 1 min. After remained stationary for 15 min, the pH of the solution was measured and the method of pH measurement of O et al (2) was performed with some modification.

The surface of each sample was evaluated using a colorimeter (CR-400, Konica Minolta, Osaka, Japan) in accordance with the Hunter's color value system. The parameters *L* (brightness), *a* (redness), and *b* (yellowness) were measured and the value of ΔE (total color difference) was calculated using the following equation:

$$= \sqrt{(L \qquad)^2 + (a \qquad)}$$

where Δ*L*, Δ*a*, and Δ*b* are the differences in *L*, *a*, and *b* values between calibration white board (*L*: 97.13, *a*: 0.31, *b*: 2.04) and sample, respectively. All samples were measure in triplicate to analyze the moisture content, pH, and color value.

Texture analysis

To measure the textural properties, samples were cut to a uniform size (2 × 2 × 2 cm). Then, hardness, cohesiveness, springiness and chewiness of the samples were evaluated using a rheometer (Sun rheometer Compac-100 II, Sun Scientific Co., Ltd, Tokyo, Japan). To measure the sample texture, a No. 1 Φ20 mm probe was used. The maximum weight was 2 kg, and the table speed was 120 mm/min. A two-bite compression test was employed and all samples were measured in triplicate.

Retrogradation analysis from isothermal crystallization kinetics

The retrogradation rate of each sample was measured using a previously described method (2) with a rheometer (Sun rheometer Compac-100 II, Sun Scientific Co. Ltd, Tokyo, Japan). To measure the hardness, samples preserved at 4°C for 0, 12, 24, 36, and 48 h were analyzed using the Avrami equation as follows:

$$\theta \qquad \frac{E_L - E_t}{E_L - E_0} \qquad e^{-kt^n} \qquad [1]$$

where θ is the fraction of non-crystallized material, E_L represents maximum hardness, E_0 is the hardness at 0 h, E_t indicates hardness at *t* h, *k* represents the rate constant, *n* is the Avrami exponent, and *t* indicates the storage time (h).

To obtain the values of hardness and time, each sample was measured at a given point using Equation 3. The Avrami exponent (*n*) was calculated using the slope of the plot represented by Equation 3. The rate constant (*k*) was determined by the y-intercept value. Time constant (*1/k*) is the reciprocal of the rate constant (*k*).

$$\log\left[-\ln\frac{E_L - E_t}{E_L - E_0}\right] = \log k + n\log t \qquad [2]$$

and the values of 50% crystallization time were calculated using *k* and *n*. The calculation was conducted following the eclipse.

$$t_{1/2:}\left(-\frac{ln0.5}{k}\right)^{\frac{1}{n}} \qquad [3]$$

Sensory evaluation

A panel of untrained 50 individuals (aged 20Φ0 years) participated in this test and analyzed the appearance, flavor, texture, moistness, and overall acceptability of samples using the nine-point scale method (strong dislike = 1 and strong like = 9). The panels received five samples (2 × 2 × 2 cm) on a white plate randomly.

Statistical analysis

All data were expressed as the mean ± standard deviation of triplicate experiments. All data obtained from measurements were evaluated by one-way ANOVA in SPSS, ver. 23.0 (IBM Corp., Armonk, NY). Significance of a difference between the means of measured experime ntal values was analyzed by Duncan's multiple-range test (p<0.05).

Result and Discussion

antioxidant activities

Phenolic compounds, which act as antioxidant agents, are found in many plants, including herbs and fruit plants, and they are classified as phenols, phenolic acids, hydroxycinnamic acid derivatives, and flavonoids (25). Antioxidants scavenge oxygen, which forms highly reactive free radicals by chelating the molecules involved in the chain reaction of the chemical reaction(25). The total phenolic contents for each part of the nipa palm: fruit-husk, 30.78 GAE mg/g extract; mature leaf, 299.06 GAE mg/g extract; and young leaf, 205.97 GAE mg/g extract(26-27). The total phenol and flavonoid contents of the samples are shown in Table 2, and these values significantly increased with an increase in the amount of nipa palm powder (p<0.01). These results are in accordance with those of previous studies regarding the addition of nipa palm to soup (20), syrup (28), and vinegar (16). In addition, Lee et al. (29) reported that the total phenol content of nipa palm stalks (20190.73 mg/100 g) was higher than that of red ginseng and blueberry. These total phenol and flavonoid contents were significantly affected by the antioxidants (27). FRAP assay involves measurement of the reducing power of compounds when they donate hydrogen atoms to ferric complexes, thereby scavenging the radical chain reaction (30). However, the FRAP assay (Table 2) did not reveal any significant difference between the samples in this study. Nagendra et al. (31) reported that the reducing power of *N. fruticans* was 147–819 mmol Fe^{2+}/100 dry weight for the whole fruit bunch, individual fruit, and endosperm. A similar result was also observed upon adding nipa palm to soup (20), wherein the contents of total phenol and flavonoid increased. However, the results of FRAP did not show significant differences between the 0% to 4% groups.

Moisture, pH, and Color

The moisture content, pH, and color value of *Sulgidduk* are shown in Table 3. The moisture content of the samples increased as the amount of nipa palm powder increased (p<0.01). These results were similar to those obtained by Kim and Hwang (20) for soup. The moisture content affects texture parameters, wherein the more water an item contains, the softer the food. The pH of samples ranged from 6.03 to 6.13, but no significant difference was observed. When pH was in the neutral region, it did not affect the retrogradation of the starch, which also did not occur effectively when the pH was 7 or higher (23). In a previous study wherein nipa palm was added to soup (11), it was reported that the addition of nipa palm powder did not significantly affect the pH in the 0% to 10% addition group, which corroborates the results found in the present study. However, Oh and Hwang (12) reported that addition of nipa palm powder to a concentration

Table 2. The results of total phenol content, flavonoid content, and FRAP of *Sulgidduk* with different amounts of nipa palm powder

Antioxidant activity	Nipa palm powder content based on rice flour (%)					F-value
	N 0%1)	N 1%	N 2%	N 3%	N 4%	(p value)
Total phenolic content (g GAE/mg)	174.71±3.02[d,2)]	187.24 ± 23.99[cd]	208.35 ± 13.12[bc]	221.54 ± 6.36[a,b]	249.91 ± 10.90[a]	12.994**
Flavonoid content (g QE/mg)	64.64 ± 2.19[e]	71.80 ± 4.24[d]	93.28 ± 1.91[c]	107.05 ± 2.08[b]	129.08 ± 6.61[a]	138.758***
Ferric-reducing antioxidant power (%)	5.00 ± 0.01	5.00 ± 0.00	5.00± 0.00	5.00± 0.00	6.00 ± 0.01	2.334NS3)

[1)]*Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.*

[2)]*Values are expressed as mean ± standard deviation.*

[a–e]*Different superscripts indicate significant differences between values in the same row, according to the Duncan's range test (p<0.05).*

***p < 0.01, ***p < 0.001.*

[3)]*NS: No significant difference.*

Table 3. Moisture content, pH values, and color of *Sulgidduk* with different amounts of nipa palm powder

Properties	Nipa palm powder content based on rice flour (%)					F-value
	N 0%[1)]	N 1%	N 2%	N 3%	N 4%	(*p* value)
Moisture (%)	33.90 ± 0.95$^{c2)}$	34.81 ± 0.66^{b}	35.41 ± 1.21^{bc}	36.30 ± 0.39^{c}	36.31 ± 0.25^{c}	11.572***
pH	6.13± 0.21	6.13 ± 0.06	6.03 ± 0.11	6.09 ± 0.59	6.11 ± 0.07	91.590NS3)
L[4)]	88.89±0.66$^{a1)}$	73.72±0.82^{b}	68.49±0.62^{c}	66.34±0.72^{d}	65.38±0.89^{d}	506.552***
a	-1.06±0.30^{d}	4.08±0.15^{c}	5.71±0.16^{b}	5.96±0.31^{ab}	6.27±0.08^{a}	943.245***
b	5.86±0.07^{d}	10.51±0.28^{c}	11.35±0.13^{b}	11.68±0.20^{ab}	11.76±0.04^{a}	679.721***
ΔE	9.20±0.57^{d}	25.17±0.85^{c}	30.58±0.60^{b}	32.75±0.75^{a}	33.73±0.82^{a}	581.903***

[1)]*Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.*

[2)]*Values are expressed as mean ± standard deviation.*

[a~c]*Different superscripts indicate significant differences between values in the same row, according to the Duncan's range test (p<0.05).*

$^{***}p$ < 0.001.

[3)]*NS: No significant difference.*

[4)]*L: lightness (0 black↔white +100), a: redness (−80 green↔red +100), b: yellowness (−80 blue↔yellow +70), ΔE: total color difference*

over 20% reduced in decreased pH of the samples due to the organic acid content in the nipa palm powder.

These results indicated that as the pH of nipa palm powder (pH 5.30) and rice powder (pH 5.36) were similar, nipa palm does not have a significant effect on the pH of *Sulgidduk*.

The *L*-values (brightness) slightly decreased when the amount of nipa palm powder increased (Table 3) (p<0.001). The color values were as follows: rice; *L*: 95.24, *a*: -1.18, and *b*: 4.67 and nipa palm; *L*: 65.06, *a*: 6.74, and *b*: 16.00. The N0 group had a value of 88.89, while the N4 group had a value of 65.38 (p<0.001). The *a*-value (redness) for N0 was -1.06, and the addition of nipa palm resulted in an increase in this value. The *b*-values (yellowness) increased for nipa palm-treated samples (from 10.51 to 11.76) compared to the N0 sample (5.86). The ΦE- value was significantly affected by the addition of nipa palm; the N0 group showed the lowest value of 9.20, while the N4 group had the highest value of 33.73 (p<0.001).

The results obtained using nipa palm sap in syrup in a previous study (24) were consistent with the results of the present study, in that the *L*-value decreased and the *a*- and *b*-value increased. The color difference in the ingredients may affect the results. The color values were as follows: rice powder; *L*: 97.13, *a*: 0.31, and *b*: 2.04, and nipa palm powder; *L*: 65.06, *a*: 6.74, and *b*: 16.00.

Textural analysis

Texture profile analysis (TPA) was used to measure the texture of *Sulgidduk*, and the hardness, cohesiveness, chewiness, and brittleness were calculated and the results is shown in Table 4. For the TPA method, two decompression times were used to imitate the chewing action in humans; this approach results in a high correlation between sensory and instrumental measurements (32). The values of hardness, cohesiveness, and chewiness decreased as the amount of

Table 4. Textural properties of *Sulgidduk* with different amounts of nipa palm powder

Properties	Nipa palm powder content based on rice flour (%)					F-value (p-value)
	N 0%1)	N 1%	N 2%	N 3%	N 4%	
Hardness (N)	5.76±0.06[a2)]	4.15±0.12[b]	4.09±0.15[b]	3.66±0.15[c]	3.63±0.20[c]	114.398***
Cohesiveness (%)	61.96±1.91[a]	59.14±1.54[a]	58.91±1.26[a]	57.58±1.52[a]	49.49±6.74[b]	6.005***
Springiness (mm)	66.37±1.63	66.55±4.24	68.56±1.51	67.04±2.55	66.55±4.24	0.255[NS3)]
Chewiness (N*mm)	2.37±0.03[a]	1.63±0.11[b]	1.65±0.06[b]	1.42±0.14b[c]	1.20±0.23[c]	33.769***

[1)] *Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.*

[2)] *Values are expressed as mean ± standard deviation.*

[a~c] *Different superscripts indicate significant differences between values in the same row, according to Duncan's range test (p<0.05).*

*** *p < 0.001.*

[3)] *NS: No significant difference*

nipa palm powder increased(p<0.01). Thus, N0 had the highest and N4 had the lowest values among the samples (p<0.01). Hardness and cohesiveness are the primary characteristics of food, and chewiness are the secondary characteristics, which can be measured based on the value of the primary characteristics (32). Cohesiveness is related to hardness because it refers to the density of the food structure (33). The denser the structure, the higher the hardness and cohesiveness values (33). This result was similar to that of a previous study involving the addition of almond powder to of *Sulgidduk* (1), resulting in decreased hardness, cohesiveness, and chewiness. However, these results were in contrast with those of a study involving the addition of *Moringa oleifera* extract (34), wherein the chewiness of *Sulgidduk* increased. The linear structure of amylose results in a tight structure that provides foods with a hard texture; further amylose is also easily crystallized (35). Adding a sub-ingredient to *Sulgidduk* reduces the content of amylose, resulting in the widening of the intermolecular gap in the structure(35). It is considered that the addition of the sub-ingredient weakens the binding force between the grains of rice and increase the moisture content, thereby decreasing the hardness, cohesiveeness, and chewiness of *Sulgidduk*.

Retarding retrogradation effect

Globally, 30% of grain products are discarded due to the retrogradation of starch before consumption (35). Retrogradation of starch refers to the phenomenon of returning to beta-starch. As the retrogradation processes occur, the surface of the food becomes hard and crispy (36). This retrogradation phenomenon reduces food digestibility and specific flavors (35). Retrogradation of starch is affected by starch type, amylose content, temperature, moisture content, pH, etc. (37). Methods of retarding retrogradation include replacing some of the raw materials with modified starch, treating hydrolytic enzymes, and adding monosaccharides and polysaccharides (7). The retardation in the retrogradation of *Sulgidduk* supplemented with nipa palm powder was analyzed using the Avrami equation at 4°C for 0, 12, 24, 36, and 48 h. As shown in Table 5, the values of the Avrami exponent (n) representing the crystallization state of *Sulgidduk* were 0.98, 0.46, 1.40, 1.19, and 0.86 for the N0, N1, N2, N3, and N4 groups, respectively. Lower Avrami exponent (n) and rate constant values and higher time constant values corresponded to stronger retrogradation retardation effects (2). Therefore, N2 had stronger retrogradation retardation effects than the N0 group, as shown in Table 5.

Table 5. Avrami exponent (n), rate constant (k), time constant (T), and T (1/2) of *Sulgidduk* with different amounts of nipa palm powder

Avrami equation analysis	Nipa palm powder content based on rice flour (%)				
	N 0%[1)]	N 1%	N 2%	N 3%	N 4%
Avrami exponent(n)[2)]	0.97202	0.46269	1.39566	1.18897	0.85610
Rate constant (k[3)]	3.54×10-1	1.05	2.59×10-1	3.40×10-1	1.13
Time constant (h) (1/k)	2.8212	0.9509	3.8593	2.9388	1.1332
T 1/2[4)]	16.7976	2.5880	47.4340	18.8935	3.1055

[1)] *Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.*

[2)] *Values obtained from the slope of plot .*

[3)] *Values obtained from the slope of plot ln(E_L-E_t) vs. time.*

[4)] *The values of 50% crystallization time was calculate by using k and n*

A previous study involving the addition of radicchio powder (2) showed similar results, whereby adding 1% sub-ingredient showed the strongest retarding retrogradation effect on *Sulgidduk*. T 1/2 is the time it takes for 50% of the sample to crystallize, which means that the higher the value, the more delayed the retrogradation of the sample. In accordance with the results of the Avrami exponent (*n*), rate constant, and time constant, the T 1/2 value were found to be the highest in the N1-N2 group. We found that the addition of 1-2% nipa palm powder may retard retrogradation. It was inferred that widening the structure of starch may have inhibited retrogradation in *Sulgidduk*.

Sensory evaluation

To evaluate the sensory preference of *Sulgidduk*, appearance, flavor, texture, moistness, and overall preference were assessed. Sensory evaluation based on the five senses of humans of sight, smell, taste, touch, and sound for the measurement of food quality means that texture has the greatest impact on scores, although this varies between individuals (21). The results of the sensory evaluation test of *Sulgidduk* with the addition of nipa palm powder are shown in Table 6. The appearance of the food was most affected by its color, size, surface properties, etc (38). The taste and flavor were evaluated when odors from foods reached olfactory receptors in the nasal cavity, which constituted almost 80% of this assessment (40). The N0 and N1 group had the highest score (7.20, 6.40) for appearance, flavor, texture and overall preference. It was found that 1% or greater nipa palm powder had a negative effect on sensory preference. These results are similar to those of a previous study assessing the addition of nipa palm powder to soup (20).

Conclusion

The purpose of this study was to use nipa palm powder in the traditional Korean food *Sulgidduk*, and to examine the antioxidant activities, quality characteristics, retarding retrogradation effects, and conduct a sensory evaluation. To measure the antioxidant activities, total phenol content, flavonoid content and FRAP assay were used. Adding nipa palm powder in Sulgidduk, the total phenol content and flavonoid content were significantly increased whereas the FRAP did not show significant difference between the sample. The moisture content was increased as the amount of nipa palm powder increased. The pH value had no significant difference among the sample. The color values of *Sulgidduk* (a and b) significantly increased with

Table 6. Sensory evaluation scores for *Sulgidduk* with different amounts of nipa palm powder

Sensory evaluation	Nipa palm powder content based on rice flour (%)					F-value (p-value)
	N0%[1)]	N 1%	N 2%	N 3%	N 4%	
Appearance	7.20±1.14[a2)]	7.28±1.74[a]	5.66±1.66[b]	5.46±1.51[b]	5.34±1.73[b]	18.894***
Flavor	6.28±1.62[a]	5.98±1.33[a]	5.20±1.59[b]	4.76±1.68[b]	4.72±1.59[b]	10.282**
Texture (Chewiness)	5.84±1.48[a]	5.90±1.79[a]	4.90±1.82[b]	4.44±1.79[bc]	3.86±1.97[d]	12.448***
Moistness	5.38±1.93[a]	5.40±2.04[a]	4.70±1.98[ab]	4.06±1.96[bc]	3.44±1.94[c]	9.32***
Overall preference	6.40±2.01[a]	6.38±1.72[a]	5.04±2.05[b]	4.56±1.89[bc]	4.00±2.04[c]	15.44***

[1)]Nipa palm. N0: without nipa palm powder, N1: with 1% nipa palm powder, N2: with 2% nipa palm powder, N3: with 3% nipa palm powder, N4: with 4% nipa palm powder.

[2)]Values are expressed as mean ± SD of triplicate observations.

a-cDifferent superscripts indicate significant differences between values in the same row, according to Duncan's range test (p<0.05).

***p < 0.01, ***p < 0.001.*

the addition of nipa palm powder, but the *L*-value decreased. The hardness, cohesiveness, and chewiness decreased with an increasing level of nipa palm powder. The N1-N2 group had the highest score of the Avrami results. The results of sensory evaluation showed that N0-N1 group had highest score among the sample. Collectively, these results suggest that the optimal level of nipa palm powder to improve the quality characteristics and retard the retrogradation effect is 1% for the production of *Sulgidduk*. This study provides evidence for the benefits of the increased use of nipa palm powder, which could lead to the development of various recipes for processing *Sulgidduk* and increasing the demand for rice cakes, thereby leading to positive effects on related industries.

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