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Physicochemical Properties and Sensory Attributes of Yanggaeng Treated with Citrus Peel Powder

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Abstract: We aimed to investigate the effect of citrus peel powder (CP) on the physicochemical, antioxidant, and sensory properties of Yanggaeng when treated with various levels (CON (0%), CP2 (2%), CP4 (4%), and CP6 (6%)) of CP. With an increase in CP content, Yanggaeng displayed a significantly elevated free radical scavenging rate, as indicated by increased 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) free radical scavenging rates, as well as ferric reducing antioxidant power (FRAP). Furthermore, the addition of CP significantly reduced the pH and increased Brix values compared to the control (CON). CP treatment also exhibited a dose-dependent effect on colorimetric properties, resulting in decreased L^* and increased a^* and b^* values. Moreover, CP addition changed the textural characteristics of Yanggaeng, escalating gumminess, hardness, and chewiness, while reducing adhesiveness. In terms of consumer preferences, Yanggaeng containing 4% CP (CP4) closely resembled CON in terms of attributes such as flavor, taste, sweetness, chewiness, purchase intent, and overall acceptance. However, Yanggaeng containing 2% (CP2) or 6% (CP6) CP led to a decreased overall preference for Yanggaeng. In conclusion, based on our findings, CP4 appears to be the most suitable choice for enhancing both the physicochemical and sensory properties of Yanggaeng. Furthermore, adding CP to Yanggaeng serves as a foundation for novel food production incorporating CP.

Keywords: citrus peel; Yanggaeng; physicochemical properties; sensory characteristics

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1. Introduction

In recent decades, global citrus fruit production and the fruit juice industry have experienced consistent growth. Citrus fruits serve a multitude of purposes, including consumption as fresh fruit, transformation into juice and concentrate, and utilization in byproducts such as essential oils [1,2]. These versatile applications extend across various sectors, including the food and beverage, cosmetics, and fragrances industries [1,2]. However, citrus fruit processing in these industries generates a significant amount of waste, primarily composed of citrus peels. The amount of citrus pomace produced can vary based on the size and variety of citrus fruit being processed, as well as the processing methods employed. Collectively, citrus peels, seeds, and residual membranes represent a substantial portion of this waste. Typically, citrus peels, seeds, and leftover membranes account for

50–60% of the overall weight of the fruit in the citrus processing industry [3]. According to a Food and Agriculture Organization (FAO) global report, 132 million tons of citrus were produced worldwide in 2020 [4]. Based on an estimate that approximately half to three-fifths of this weight constitutes citrus peel, the global production of citrus peel waste could be roughly estimated at 66–79 million metric tons.

Citrus pomace stands as a significant waste byproduct in the citrus industry, and without proper management, it can lead to environmental contamination and various adverse consequences. The primary concern revolves around the release of methane gas during the decomposition of citrus peel in landfills [5,6]. Methane is a powerful greenhouse gas that adds to the phenomenon of global climate change, and its emission escalates when substantial quantities of citrus peel are disposed of in landfills [5]. Additionally, the practice of open burning to dispose of citrus waste presents another challenge. The burning of pomace is prevalent in certain regions, particularly in developing nations, and results in the emission of carbon dioxide and other greenhouse gases into the atmosphere [6–8]. Furthermore, incinerating waste byproduct releases particulate matter and volatile organic compounds, pollutants that can have severe detrimental effects on both human health and the environment [6–8]. Given the harmful consequences of the considerable volume of citrus peel waste, it is imperative to explore strategies for converting this waste into valuable products that can yield economic benefits. Therefore, identifying sustainable and economically viable approaches to utilize citrus peel is essential to enhance the efficiency of the citrus processing industry.

The most efficient approach to minimizing methane and carbon dioxide production stemming from citrus peels is to utilize them across various industrial sectors rather than merely disposing of them. Citrus peels are nutrient-dense resources, containing dietary fiber and an array of essential vitamins and minerals such as vitamin C, folate, potassium, and essential oils, which render them nutritionally valuable [2,9–13]. Furthermore, citrus peels are rich in physiologically active functional polyphenols, including phenolic acids and flavonoids. The presence of these physiologically active compounds has prompted extensive research into possible applications of citrus peels within the food sector. Their ability to enhance nutritional composition, flavor, and aroma in various desserts has garnered significant attention, making them a focal point for research and product development across different dessert categories, including pan bread [14], yukgwa [15], rice cakes [16], sponge cakes [17], cookies [18], and madeleines [19].

Yanggaeng is a quintessential dessert snack that holds a special place in the hearts of Koreans, being one of their preferred nutrient-rich foods. At its core, Yanggaeng's primary ingredient is agar, mainly composed of dietary fiber. Yanggaeng not only possesses significant water-retention capabilities that enhance the feeling of fullness, but also offers notable potential for alleviating constipation. With modern consumers becoming increasingly environmentally conscious, there is a growing demand for desserts made from fruit waste byproducts. These ethical trials include cakes [20] and muffins [21] made from grape skin powder, puff pastries made from olive-pomace oil [22], or jam made from tomato pomace [23].

Consequently, this study aims to assess the impact of introducing varying concentrations of citrus peel powder (CP) into Yanggaeng, with the intention of exploring its potential as a functional component. The overarching objective of this research is to provide essential insights for the effective utilization of CP as a food additive. Additionally, the study aims to promote its consumption by innovatively developing high-value-added food products, thereby contributing to a reduction in potential food waste. In the absence of a specific precedent report regarding the addition of citrus peel as a food additive in Yanggaeng, we decided to conduct a comparison study. We compared Yanggaeng with 2% to 6% CP added to the conventional Yanggaeng, which served as the control with no citrus peel added. To comprehensively understand the physicochemical characteristics of Yanggaeng containing citrus peel pomace, the analysis includes proximate analysis and an evaluation of physicochemical attributes, antioxidative capabilities, and textural traits

compared to the conventional Yanggaeng. Furthermore, to gauge contemporary consumer responses to these novel offerings, consumer preferences were also surveyed.

2. Materials and Methods

2.1. Materials and Methods

Dried citrus peel (*Citrus unshiu*, Rutaceae family) was purchased from One Nature (Pocheon, Republic of Korea). These peels were mechanically processed using an automated grinder (HR2904; Philips Co., Amsterdam, The Netherlands). The resulting material, citrus peel powder (CP), was subsequently stored at approximately −70 °C until CP was ready for further formulation.

2.2. Formulation and Preparation of Yanggaeng

Yanggaeng was prepared following a recipe that had been peer reviewed [24]. To formulate the Yanggaeng mixture, 10 g of agar was added to 400 g of water and left to soak for 10 min before boiling over medium heat for approximately 2 min. Apart from the control (CON) sample, variations of Yanggaeng were prepared, each containing 2% (CP2), 4% (CP4), or 6% (CP6) CP, as detailed in Table 1. CP was incorporated into the water–agar mixture, followed by the addition of white bean paste and sugar. The mixture was gently simmered at low heat for 10 min. Subsequently, the Yanggaeng mixture was poured into a square mold with a thickness of 2 cm and allowed to solidify. After a cooling period of 2 h, Yanggaeng was prepared for use in subsequent experimental procedures.

Table 1. Formula of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	CP2	CP4	CP6
White bean paste	49.5	48.5	47.5	46.5
Three-times distilled water	39.6	39.6	39.6	39.6
White sucrose	9.9	9.9	9.9	9.9
Agar powder	1.0	1.0	1.0	1.0
Citrus peel powder	0	1.0	2.0	3.0

[1] CON: Yanggaeng containing 0% citrus peel powder; CP2: Yanggaeng containing 2% citrus peel powder; CP4: Yanggaeng containing 4% citrus peel powder; CP6: Yanggaeng prepared with 6% citrus peel powder.

2.3. Proximate Analaysis of Yanggaeng

The proximate indices of Yanggaeng, including crude ash, crude fat, moisture, and crude protein contents, were evaluated using established protocols [25]. Carbohydrate content (%) was determined using the following formula:

$$\text{Carbohydrate content (\%)} = 100 - (\text{crude ash} + \text{crude fat} + \text{moisture} + \text{crude protein})$$

2.4. Antioxidant Properties of Yanggaeng

To evaluate the antioxidative attributes of Yanggaeng, 2.5 g of Yanggaeng was dissolved in 50 mL of 70% ethanol and incubated for 24 h. In succession, Yanggaeng was separated by centrifugation at 3000× *g* for 10 min. Quantification of total polyphenols, total flavonoids, scavenging activity against DPPH and ABTS radicals, and FRAP were determined following established protocols [17,26–29]. To measure the DPPH and ABTS radical scavenging activity, DPPH solution (300 µM, Sigma-Aldrich Co., St. Louis, MO, USA) and ABTS solution (7 mM, Sigma-Aldrich Co.) were separately added to the sample solution.

2.5. Physicochemical Properties and Hunter's Color Values of Yanggaeng

Two grams of Yanggaeng was dissolved in 20 mL of three-times distilled water, and subsequently, the supernatant was isolated by centrifugation at 3000× *g* for 10 min using a centrifuge (Hanil Science Co., Ltd., Daejeon, Republic of Korea). Following the dissolution procedure, both pH and Brix values were measured. For pH measurements, a pH

meter (Orion Star, Thermo Fisher Scientific [Korean branch], Seoul, Republic of Korea) was used, whereas Brix values were ascertained using a Brix meter (Hanna Instruments, Woonsocket, HI 96801, USA). The lightness (L^*), redness (a^*), and yellowness (b^*) of Yanggaeng containing CP were assessed using a validated colorimeter (LC100, Tintometer Ltd., Amesbury, UK).

2.6. Texture Profile Analysis of Yanggaeng

For the texture profile analysis (TPA), individual portions of Yanggaeng were molded into cubic shapes measuring approximately 2 cm^3. TPA parameters, including hardness, adhesiveness, resilience, springiness, cohesion, gumminess, and chewiness, were evaluated using a rheometer (Stable Micro System Co., Ltd., Surrey, UK). The texture analyzer was fitted with a flat-bottomed probe with a diameter of 30 mm. The machine-driven testing parameters were configured with a compression rate of 60%, automatic trigger load of 0.5 N, testing speed of 1 mm/s, and pre-and post-test speeds of 2 mm/s.

2.7. Consumers' Preferences of Yanggaeng

The assessment of consumer preferences involved 50 students who were selected from Dankook University. The Institutional Review Board of Dankook University granted approval for this study (DKU-2022-03-201-001). Prior to the tasting session, participants were briefed on the application of a 9-point categorical scale. They evaluated attributes, such as color, aroma, taste, sweetness, flavor, chewiness, overall liking, and inclination to make a purchase.

2.8. Statistical Analysis

Each experimental outcome was measured on three separate occasions to derive average values and standard deviations. One-way analysis of variance (ANOVA) was performed using XLSTAT 2012 (Addinsoft, Inc., Paris, France). The mean values were compared, followed by Duncan's post hoc test to assess variations attributable to the different treatments.

3. Results and Discussion

3.1. Proximate Analaysis of Yanggaeng

Table 2 shows the results of Yanggaeng made with citrus peel powder. Table 2 shows the results of proximate analysis of Yanggaeng prepared with varying concentrations of citrus peel. The results of proximate analysis of the citrus peel were 69.97% carbohydrates, 11.64% moisture, 5.40% crude protein, 2.17% crude fat, 2.05% crude ash, 8.77% crude fiber, and 0.15% organic acid [14]. The moisture content was 49.42% for the CON group, 46.33% for CP2, 48.30% for CP4, and 48.59% for CP6. CP2 exhibited the highest moisture content among the Yanggaeng groups ($p < 0.05$). The highest crude fat composition was noted in CP6 ($p < 0.001$). It is likely that the increased fatty acids in CP6 include linoleic acid, palmitic acid, α-linolenic acid, and oleic acid, as Mastro et al. reported them as being the major fatty acids in citrus peel [30]. The crude ash and protein contents of Yanggaeng remained unchanged across all treatments. Furthermore, the carbohydrate content was remarkably higher in CP2 than in the other treatments ($p < 0.001$), which may be associated with the reduced water content observed in CP2.

Table 2. Proximate analytical results of Yanggaeng containing citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
Moisture	49.42 ± 0.32 [a]	46.33 ± 0.81 [b]	48.30 ± 0.51 [a]	48.59 ± 0.37 [a]
Crude ash	0.35 ± 0.04 [NS]	0.34 ± 0.05 [NS]	0.35 ± 0.05 [NS]	0.39 ± 0.08 [NS]
Crude fat	0.13 ± 0.02 [b]	0.12 ± 0.01 [b]	0.14 ± 0.00 [b]	0.18 ± 0.02 [a]
Crude protein	0.05 ± 0.01 [NS]	0.05 ± 0.01 [NS]	0.06 ± 0.01 [NS]	0.06 ± 0.00 [NS]
Carbohydrate [2]	50.05 ± 0.28 [b]	53.15 ± 0.76 [a]	51.15 ± 0.55 [b]	50.78 ± 0.46 [b]

[1] Treatments are shown in Table 1. [2] Carbohydrate = 100 − (crude ash + crude fat + moisture + crude protein). Data are presented as means ± standard deviation (n = 3). Different lowercase letters in the same column are significantly different ($p < 0.05$). Abbreviation: NS, not significant.

3.2. Antioxidative Properties of Yanggaeng

Table 3 depicts the outcomes of total phenolic (TPC) and flavonoid content (TFC) analysis in Yanggaeng containing CP. In a peer-reviewed study by Brito et al., the analysis of phenolic chemicals in three different types of citrus peels revealed TPC values ranging from 23.14 to 36.22 mg gallic acid equivalent (GAE)/g and TFC values ranging from 12.29 to 24.90 mg quercetin equivalent (QE)/g [31]. In our study, we observed that the TPC of Yanggaeng significantly increased after CP treatment compared to that in CON ($p < 0.05$). Among the CP-containing Yanggaeng groups, CP6 resulted in a 1.12-fold increase in polyphenol content compared to that in the CON. TFC exhibited a trend similar to that of TPC following CP treatment. Flavonoid contents increased by 5.07-fold, 10.53-fold, and 14.40-fold in the CP2, CP4, and CP6 groups, respectively, compared to CON ($p < 0.001$). These findings can be linked to the elevated concentrations of flavonoids, such as naringin, hesperetin, rutin, deosmin, and tanveretin, present in citrus peel [31,32].

Table 3. Total phenolic content and total flavonoid content of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
TPC (mg GAE/g)	20.28 ± 1.85 [c]	22.65 ± 0.90 [ab]	25.90 ± 6.98 [ab]	28.68 ± 3.08 [a]
TFC (mg QE/g)	0.44 ± 1.26 [b]	2.24 ± 0.82 [b]	4.65 ± 1.41 [a]	6.35 ± 0.26 [a]

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation (n = 3). Different lowercase letters in the same column are significantly different ($p < 0.05$). Abbreviations: TPC, total phenol content; GAE, gallic acid equivalent; TFC, total flavonoid content; QE, quercetin equivalent.

Table 4 indicates the results of the free radical scavenging rates as well as the FRAP of Yanggaeng. In a previous study, CP-treated jelly had elevated levels of both TPC and TFC, as well as DPPH and ABTS free radical scavenging rates, indicating substantial antioxidant activity [33]. Similarly, in this study, the DPPH free radical scavenging rate was lowest in CON (20.01%). However, Yanggaeng prepared with CP2, CP4, and CP6 had a significantly increased DPPH free radical scavenging rate, by 1.27-fold, 1.34-fold, and 1.66-fold, respectively ($p < 0.05$). ABTS free radical scavenging rates were also the lowest in CON (18.70%), but progressively increased with the addition of CP. ABTS free radical scavenging rates were elevated 1.29-fold, 1.44-fold, and 1.69-fold in the CP2, CP4, and CP6 groups, respectively ($p < 0.0001$). The FRAP values exhibited a dose-dependent response to increasing CP content in Yanggaeng, mirroring the trend observed for the ABTS free radical scavenging rates. FRAP values were the lowest in CON (3.75 mM $FeSO_4$), but steadily and significantly increased with higher CP addition. The FRAP values increased 7.77-fold, 22.53-fold, and 40.87-fold in the CP2, CP4, and CP6 groups, respectively. In this study, a robust positive correlation was observed in the ABTS radical scavenging ability, FRAP, TFC, and TPC. Therefore, the antioxidant activity of Yanggaeng containing CP was likely attributable to the presence of TFC and TPC.

Table 4. Antioxidative activity of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
DPPH free radical scavenging rate (Inhibition %)	20.01 ± 7.32 ^{b}	25.49 ± 5.42 ^{ab}	26.90 ± 4.99 ^{ab}	33.17 ± 5.96 ^{a}
ABTS free radical scavenging rate (Inhibition %)	18.70 ± 1.15 ^{d}	24.05 ± 0.17 ^{c}	27.02 ± 0.30 ^{b}	30.54 ± 0.44 ^{a}
FRAP (mM $FeSO_4$/g)	3.75 ± 0.75 ^{d}	29.13 ± 1.94 ^{c}	84.50 ± 1.06 ^{b}	153.25 ± 1.06 ^{a}

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation (n = 3). Different lowercase letters in the same column are significantly different ($p < 0.05$).

3.3. pH and Brix of Yanggaeng

Table 5 provides the pH and Brix values of Yanggaeng. The pH was higher in CON than in the Yanggaeng groups with added citrus peel. Additionally, the inclusion of citrus peel in Yanggaeng resulted in a dose-dependent pH reduction. As a result, CP6 exhibited the lowest pH (6.20; $p < 0.0001$), and this decline in pH was likely attributable to the organic acids present in CP, such as malic, citric, acetic, and ascorbic acids [34,35]. Similarly, desserts, such as sponge cakes or cookies incorporating CP, tend to exhibit a decrease in pH compared to that of CON [17,18,36]. Notably, the CON group had a higher Brix value than the Yanggaeng group with added citrus peels, except for CP4 (CP4 > CON > CP6 > CP2, $p < 0.0001$).

Table 5. pH and Brix of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
pH	6.94 ± 0.06 ^{a}	6.51 ± 0.03 ^{b}	6.39 ± 0.04 ^{c}	6.20 ± 0.04 ^{d}
Brix	3.10 ± 0.00 ^{b}	2.70 ± 0.00 ^{d}	3.23 ± 0.06 ^{a}	2.90 ± 0.00 ^{c}

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation (n = 3). Different lowercase letters in the same column are significantly different ($p < 0.05$).

3.4. Color Values of Yanggaeng

Figure 1 shows the external feature and Table 6 displays the colorimetric values of CP-added Yanggaeng. The L^* values were 43.50 for CON, 32.90 for CP2, 28.13 for CP4, and 26.63 for CP6. The CON group exhibited higher L^* values than the groups with added CP. Moreover, there was a statistically significant reduction in L^* values as the concentration of CP increased ($p < 0.0001$). Generally, the a^* and b^* values exhibited a noticeable dose-dependent increase after CP treatment. The a^* values in Yanggaeng samples were −0.80 for CON, 4.87 for CP2, 7.97 for CP4, and 9.00 for CP6. The CON group showed the lowest a^* value, whereas the CP group displayed the highest a^* value, with significant differences observed between the Yanggaeng groups ($p < 0.0001$). Regarding the b^* values, they were 3.23 for CON, 19.97 for CP2, 20.03 for CP4, and 20.57 for CP6. The CON group exhibited the lowest b^* value, whilst CP6 showed the highest b^* value, indicating significant differences among the Yanggaeng groups ($p < 0.0001$). Consistent with these observations, Lee et al. noted that adding peel powder from citrus mandarin to pan bread resulted in reduced a^* and b^* values compared to the control group [14]. The presence and concentration of carotenoid pigments in food can affect its overall color and lightness. Foods such as carrots [37,38] and sweet potatoes [39], which have high concentrations of carotenoids, tend to have brighter and more vibrant colors [40]. Accordingly, treatment with CP influenced the colorimetric properties, and this effect was likely attributable to the carotenoid pigments found in citrus fruits.

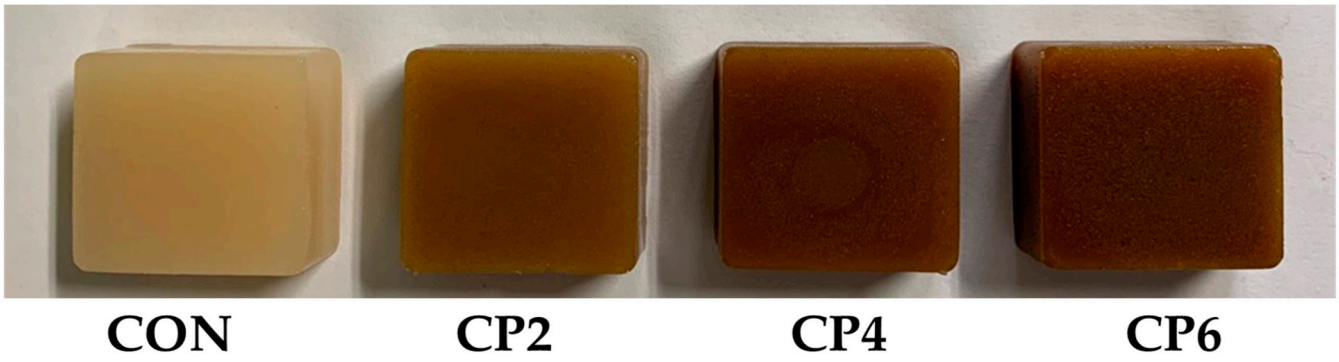


Figure 1. External feature of Yangquan made with citrus peel powder.

Table 6. Color values (*L**, *a**, *b**) of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
*L**	43.50 ± 0.10 [a]	32.90 ± 0.10 [b]	28.13 ± 0.40 [c]	26.63 ± 0.20 [d]
*a**	−0.80 ± 0.00 [d]	4.87 ± 0.12 [c]	7.97 ± 0.25 [b]	9.00 ± 0.10 [a]
*b**	3.23 ± 0.12 [c]	19.97 ± 0.32 [b]	20.03 ± 0.12 [b]	20.57 ± 0.15 [a]

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation ($n = 3$). Different lowercase letters in the same column are significantly different ($p < 0.05$).

3.5. Textural Properties of Yanggaeng

Table 7 presents the findings regarding the textural properties of Yanggaeng containg CP. The incorporation of CP into Yanggaeng led to an increase in its hardness compared with that of CON. CP4 exhibited the highest hardness (CON < CP2 < CP6 < CP4; $p < 0.0001$). Conversely, adhesiveness was higher in CON Yanggaeng; however, CP treatment resulted in decreased adhesiveness ($p < 0.01$). In particular, CP4 had the lowest adhesiveness compared with the Yanggaeng-containing groups of CP2 or CP6 (CON > CP6 > CP2 > CP4). Gumminess and chewiness levels decreased in CON, whereas CP treatment increased both gumminess and chewiness ($p < 0.001$). Interestingly, the values of adhesiveness, resilience, cohesion, and springiness remained consistent across all treatment groups. The addition of CP leads to a decrease in adhesiveness, accompanied by an increase in gumminess, hardness, and chewiness, owing to the effect of the powder particles on the formation of the solid-like structure. However, based on textural properties, resilience, cohesion, and springiness remained unaffected by the introduction of CP.

Table 7. Textural properties of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
Hardness (g)	1860.08 ± 26.62 [d]	1929.00 ± 17.10 [c]	2079.32 ± 8.88 [a]	1992.34 ± 27.62 [b]
Adhesiveness (g.s)	−106.02 ± 35.35 [a]	−169.21 ± 9.38 [b]	−223.12 ± 41.48 [c]	−158.42 ± 8.55 [ab]
Resilence (%)	5.33 ± 1.04 [NS]	6.35 ± 0.25 [NS]	5.52 ± 0.65 [NS]	5.61 ± 0.49 [NS]
Cohesion	0.24 ± 0.07 [NS]	0.32 ± 0.01 [NS]	0.30 ± 0.03 [NS]	0.31 ± 0.01 [NS]
Springiness (%)	99.18 ± 0.00 [NS]	99.32 ± 0.24 [NS]	99.32 ± 0.24 [NS]	98.50 ± 1.55 [NS]
Gumminess	406.38 ± 22.55 [b]	617.76 ± 29.18 [a]	640.68 ± 20.12 [a]	619.60 ± 20.84 [a]
Chewiness	403.05 ± 22.36 [b]	613.54 ± 29.01 [a]	636.58 ± 19.77 [a]	610.29 ± 22.92 [a]

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation ($n = 3$). Different lowercase letters in the same column are significantly different ($p < 0.05$). Abbreviation: NS, not significant.

3.6. Consumers' Preferences of Yanggaeng

Table 8 shows the results of the consumers' preferences of Yanggaeng prepared using CP. To gauge consumer preferences for Yanggaeng containing CP, an untrained general public member was given a 9-point hedonic scale. Compared to CON, CP2 and CP6 had lower preference scores for sweetness, flavor, overall acceptance, taste, and purchase intent. However, CP4 received similar consumer preference scores for flavor ($p < 0.05$), sweetness ($p < 0.05$), taste ($p < 0.05$), overall acceptance ($p < 0.0001$), and purchase intent ($p < 0.05$) as CON. There were no significant differences in preferences for color or scent.

Table 8. Consumers' preferences of Yanggaeng made with citrus peel powder.

	Treatments (%)			
	CON [1]	**CP2**	**CP4**	**CP6**
Color	6.62 ± 1.75 ^{NS}	6.04 ± 1.99 ^{NS}	6.92 ± 1.40 ^{NS}	6.72 ± 1.73 ^{NS}
Scent	6.00 ± 1.70 ^{NS}	5.69 ± 1.78 ^{NS}	6.49 ± 1.62 ^{NS}	5.80 ± 2.11 ^{NS}
Flavor	6.48 ± 1.93 ^{a}	5.63 ± 2.01 ^{b}	6.39 ± 1.70 ^{ab}	5.56 ± 2.04 ^{b}
Sweetness	6.80 ± 1.43 ^{a}	5.92 ± 1.82 ^{b}	6.45 ± 1.72 ^{ab}	5.80 ± 1.91 ^{b}
Taste	6.92 ± 1.70 ^{a}	5.96 ± 2.08 ^{bc}	6.45 ± 1.81 ^{ab}	5.50 ± 2.21 ^{c}
Chewiness	6.16 ± 1.83 ^{ab}	6.08 ± 1.95 ^{ab}	6.84 ± 1.55 ^{a}	5.82 ± 2.24 ^{b}
Overall acceptance	6.84 ± 1.66 ^{a}	5.59 ± 2.16 ^{b}	6.65 ± 1.79 ^{a}	5.24 ± 2.11 ^{b}
Purchase intent	6.08 ± 2.18 ^{a}	5.35 ± 2.40 ^{ab}	6.22 ± 1.84 ^{a}	4.98 ± 2.34 ^{b}

[1] Treatments are shown in Table 1. Data are presented as means ± standard deviation ($n = 3$). Different lowercase letters in the same column are significantly different ($p < 0.05$). Abbreviation: NS, not significant.

The correlation matrix presented in Table 9 indicates a robust positive correlation between taste preference and sweetness preference (0.975; $p < 0.0001$). Chewiness preference followed a similar trend to that of sweetness and taste, with CP4 resulting in the highest chewiness rating (6.84 out of 9.00), whereas CP6 led to the lowest chewiness rating (5.82 out of 9.00). The chewiness preference was significantly and negatively correlated with adhesiveness among textural properties (−0.578; $p < 0.05$). The overall acceptance scores for CON (6.84 out of 9.00) and CP4 (6.65 out of 9.00) did not differ significantly. However, the addition of CP2 and CP6 significantly decreased the overall acceptance of Yanggaeng ($p < 0.0001$). As a result, there was no statistically significant difference in purchase intent between the CON group (with a score of 6.08 out of 9.00) and the CP4 group (with a score of 6.22 out of 9.00). Nonetheless, the application of CP2 and CP6 reduced purchase intent (5.35 and 4.98 out of 9.00, respectively), as observed in the overall acceptance. The correlation matrix results indicated that the overall acceptance was significantly and positively correlated with scent, flavor, sweetness, taste, and chewiness preferences (0.700, 0.986, 0.971, 0.969, and 0.684, respectively). In addition, purchase intent exhibited a strong positive correlation with scent, flavor, sweetness, taste, chewiness, and overall acceptance (0.791, 0.964, 0.915, 0.924, 0.817, and 0.977, respectively). Consequently, CP4 garnered high purchase intent due to its similar or higher ratings of flavor, sweetness, taste, chewiness, and overall acceptance compared to CON.

Table 9. Correlation matrix for variables.

	Texture							Consumers' Preferences							Antioxidative Properties				
	Hardness	**Adhesiveness**	**Resilence**	**Cohesion**	**Springiness**	**Gumminess**	**Chewiness**	**Color**	**Scent**	**Flavor**	**Sweetness**	**Taste**	**Chewiness**	**Overall Acceptance**	**Purchase Intention**	**TPC**	**TFC**	**DPPH**	**ABTS**	**FRAP**
Hardness																				
Adhesiveness	**−0.757**																			
Resilence	−0.146	−0.282																		
Cohesion	0.321	−0.399	**0.794**																	
Springiness	−0.135	−0.053	0.122	−0.039																
Gumminess	**0.769**	**−0.756**	0.382	**0.719**	−0.057															
Chewiness	**0.764**	**−0.760**	0.387	**0.718**	−0.011	**0.999**														
Color	0.507	−0.229	−0.527	−0.210	−0.056	−0.029	−0.031													
Scent	0.573	−0.488	−0.348	−0.194	0.257	0.066	0.079	**0.757**												
Flavor	−0.055	0.051	−0.409	−0.559	0.309	−0.561	−0.547	0.523	**0.763**											
Sweetness	−0.254	0.228	−0.403	**−0.623**	0.292	**−0.711**	**−0.698**	0.427	**0.620**	**0.978**										
Taste	−0.339	0.237	−0.295	**−0.599**	0.351	**−0.709**	**−0.694**	0.227	0.535	**0.942**	**0.975**									
Chewiness	0.545	**−0.578**	−0.164	−0.103	0.367	0.168	0.187	0.473	**0.932**	**0.699**	0.549	0.543								
Overall acceptance	−0.118	0.072	−0.348	−0.559	0.336	**−0.581**	−0.566	0.391	**0.700**	**0.986**	**0.971**	**0.969**	**0.684**							
Purchase intention	0.031	−0.099	−0.292	−0.463	0.387	−0.413	−0.395	0.390	**0.791**	**0.964**	**0.915**	**0.924**	**0.817**	**0.977**						
TPC	**0.603**	**−0.650**	0.227	0.358	0.101	0.560	0.566	0.063	0.431	0.002	−0.149	−0.112	**0.583**	0.009	0.177					
TFC	**0.714**	−0.500	−0.129	0.280	−0.280	**0.700**	**0.689**	0.360	0.054	−0.496	**−0.615**	**−0.735**	−0.071	−0.576	−0.510	0.232				
DPPH	0.527	−0.279	0.167	**0.642**	−0.449	**0.590**	0.569	0.248	−0.046	−0.509	**−0.578**	**−0.678**	−0.153	**−0.600**	−0.536	0.319	0.535			
ABTS	**0.753**	−0.508	0.083	**0.584**	−0.313	**0.824**	**0.810**	0.294	0.021	**−0.593**	**−0.716**	**−0.822**	−0.072	**−0.679**	**−0.584**	0.375	**0.895**	**0.831**		
FRAP	**0.657**	−0.380	−0.067	0.419	−0.358	**0.640**	0.625	0.445	0.010	−0.520	**−0.617**	**−0.770**	−0.180	**−0.627**	**−0.586**	0.158	**0.916**	**0.779**	**0.949**	

Values in bold are significantly different at $p < 0.05$.

4. Conclusions

The purpose of this study was to explore how CP influences the physicochemical attributes and sensory characteristics of Yanggaeng. In summary, CP serves as a natural and edible source of antioxidants in Yanggaeng, making it a potential choice for consumers seeking eco-friendly ethical desserts and improved attributes through alterations in the physicochemical properties via the addition of natural additives. Notably, as the amount of CP increased, Yanggaeng exhibited a reduction in oxidative stress, as evidenced by increased free radical scavenging rates, and FRAP. These antioxidant effects can be ascribed to the elevated levels of TPC and TFC found in CP. Moreover, the addition of CP significantly reduced the pH and increased the Brix values compared with CON. Additionally, CP treatment exhibited a dose-dependent effect on color attributes, resulting in decreased L^* values and increased a^* and b^* values. Furthermore, CP treatment notably modified the texture of Yanggaeng, enhancing its hardness, gumminess, and chewiness. However, with CP4, the adhesiveness was reduced compared with that in the other groups. Regarding consumer preferences, Yanggaeng with CP4 was perceived as most closely resembling CON in terms of attributes such as sweetness, flavor, chewiness, taste, purchase intent, and overall acceptance, whereas CP2 and CP6 led to a decrease in overall preference for Yanggaeng. Based on our findings, it is reasonable to conclude that CP4 is the most suitable for enhancing the physicochemical and sensory properties of Yanggaeng. This study bestows foundational data for the development of novel food products containing CP.

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