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Cookie Quality Characteristics Influenced by the Proportion of Wheat Flour Replaced by *Artemisia princeps* Leaf Powder

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Abstract

To develop quality-improved bakery products, the influence of the partial replacement of wheat flour by *Artemisia princeps* leaf powder (APP) on the quality characteristics of cookies, including antioxidant activities, was investigated. Studies were carried out to evaluate the addition of different percentages of APP on the quality characteristics of cookies prepared by incorporating APP (1-4%) into wheat flour. The incorporation of APP significantly affected the cookies' physicochemical parameters and sensory acceptance attributes. Such incorporation at different levels significantly reduced moisture content while increasing the cookie dough's density ($p<0.05$). The spread ratio, loss rate, L*, and b* values of the cookies decreased, but their hardness and a* value increased significantly with increasing levels of APP substitution ($p<0.05$). 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) radical scavenging activities were significantly increased ($p<0.05$) with higher APP substitution and were well-correlated. Hedonic sensory results showed that cookies fortified with 2% APP generally received satisfactory and acceptable acceptance scores. Consumers seemed to prefer the cookie texture in terms of chewiness when the samples were softer and lighter but less reddish, whereas taste acceptance may be a dominant factor in overall acceptability.

Keywords: *Artemisia princeps* leaf powder, wheat cookie, physicochemical properties, consumer acceptability, antioxidant properties

Introduction

The food industry is increasingly interested in plant-based food ingredients due to their diverse functional properties and the growing consumer demand for healthy foods of natural origin. In particular, the bakery products market is continuously growing worldwide and the food industry is interested in developing novel food ingredients suitable for new formulations (Cheng et al., 2023). Cookies are a widely consumed bakery product worldwide due to their affordable cost, taste, convenience, and relatively long shelf life (Blanco Canalis et al., 2020), and novel food ingredients are easily added to their formulation. Thus, the addition of plant-derived food ingredients to cookies could be a promising and health-promoting strategy to increase the consumption of healthy food ingredients in a convenient diet (Klopsch et al., 2019).

Artemisia princeps Pamp. belonging to the Asteraceae family, is a perennial herbaceous plant widely distributed in East Asia (Zhang et al., 2018). The powdered leaves are commonly used as a tea, spice, and cooking ingredient, and have also been used in traditional medicine to treat asthma, diarrhea, and many circulatory disorders (Karabegovic et al., 2011), as well as colic pain, vomiting, ulcers, dysmenorrhea, and cancer (Trinh et al., 2011). The leaves contain bioactive compounds such as phenolics and flavonoids (Choi et al., 2004), and have been reported to have antioxidant (Toda, 2005), anti-atherosclerotic (Han et al., 2009), anti-inflammatory (Joh et al., 2010), anti-obesity (Kim et al., 2010), antibacterial (Trinh et al., 2011), and anticoagulant (In et al., 2020) effects. In addition, the unique sensory properties of *Artemisia princeps* leaf powder (APP) make it widely applicable in the food industry.

In recent years, the use of plant-derived food ingredients such as *Stachys sieboldii* leaf (Kim & Lee, 2019) and aronia powder (Hwang & Kim, 2023) with improved health and nutritional benefits have been reported; therefore, there is a continuous need for their incorporation in bakery products such as cookies. Much research has been devoted to the use of APP in the production of sponge cake (Choi, 2016), sulgidduk (Ahn, 2019), and pan bread (Woo & Lee, 2021). However, to date, the application and information of APP in cookie production for new product development has not been reported, except for a limited study conducted by Park et al. (2014). Their study provided some selected information on the

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physicochemical properties and sensory results of the cookies containing 0-5% mugwort powder, but unfortunately, the information was limited and especially the sensory study showed inconclusive results. Therefore, in this study, we tried to evaluate the suitability of using APP to improve the quality and antioxidant properties of cookies. We limted the level of APP incorporation up to 4%, and measured $ABTS^{+}\cdot$ radical scavenging capacity, DPPH radical scavenging capacity and correlation analysis for a more comprehensive and systematic study. In additior, current study examined the optimum concentration of APP incorporation in terms of consumer acceptability.

Materials and Methods

Materials

All recipes were prepared using common ingredients purchased from a local market or from online stores. The ingredients were commercially available soft wheat flour (1.3% fat, 8% protein, 13% moisture; CJ Cheiljedang, Seoul, Korea), white granulated sugar (CJ Cheiljedang, Seoul, Korea), salt-free butter (Seoul Milk Co., Yangju, Korea), salt (Chung Jung Won, Seoul, Korea), and eggs. APP was purchased from Garunara (Seoul, Korea).

Cookie formulation and preparation

The standard cookies' recipe consisted of 200 g (100%) of flour (white wheat flour as a control), 90 g unsalted butter, 100 g white granulated sugar, and 50 g egg, giving 440 g of control dough. Cookies containing APP were prepared by replacing wheat flour with APP at 1% (2 g), 2% (4 g), 3% (6 g), and 4% (8 g), respectively. Samples were coded as control (recipe without APP), APP1, APP2, APP3, and APP4 for recipes in which 1-4% of the wheat flour was replaced by APP.

For the cookie dough, butter, sugar, and eggs were creamed in a kitchen mixer (5K5SS, KitchenAid Inc., St. Joseph, MI, USA) at speed 2 for 2 minutes, scraping down every minute. Wheat flour and an appropriate amount of APP were then added and mixed at speed 2 for 3 minutes. The dough was stored in a refrigerator at 4°C for 30 min before being rolled out. To make cookies, the dough was slightly flattened with the palm of the hand, rolled out to a uniform thickness of 4 mm and cut into circular shapes of 5 cm in diameter. The dough pieces were then placed on a baking tray lined with baking paper and baked at 170°C for 10 min in a preheated oven (KXS-4G+H, Salvia industrial S.A., Lezo, Spain). After cooling at room temperature for 30 min, the cookies were stored in sealed plastic bags to prevent moisture changes before further analysis.

Moisture content and density of cookie dough

Moisture content of cookie dough was measured by air-oven method. Specific amount (approximately 5 g) of sample was constantly weighted at 105°C in an oven (FOL-2, Jeio Tech Co., Daejeon, Korea), and the results were reported on a wet basis (%, w.b.). Dough density measurements were performed in a 30 mL mass cylinder by water displacement (Kim & Chung, 2017; Lee et al., 2017).

Spread ratio and loss rate of cookies

The spread ratio of the cookies was determined using the AACC method 10-50D (AACC, 2000). Diameter was measured using a caliper gauge by placing six cookies edge to edge. The diameter of the six cookies was measured again after each cookie was rotated 90° and the average cookie diameter was calculated. Six cookies were stacked and their thickness was measured. The cookies were stacked in random order and the thickness was measured again and the average cookie thickness was calculated. Cookie spread ratio was calculated by dividing the average cookie diameter by the average cookie thickness. Loss rate was expressed as a percentage of the weight ratio between before and after baking.

Hardness and color of cookies

The hardness of the baked cookies was measured using a texture analyzer (LRX*Plus*, Lloyd Instrument Limited, Fareham, Hampshire, UK) in compression mode via a 3-point flexure test using a 3-point flexure rig, a trigger force of 0.05 N and a load cell of 100 N. The texture test was performed at a test speed of 1.0 mm/s, a distance of 10 mm and the distance between the two bottom supports was set to 40 mm. The peak value of the breaking force (maximum) was recorded as the hardness at a point where the cookies were broken into two large pieces (Chakraborty et al., 2009). The peak force to break the cookies was reported as the breaking force in N.

Color determinations were made on the cookie surface using a Chroma Meter CR-600d colorimeter (Minolta Co., Osaka, Japan). CIE-LAB parameters (lightness, L*, white to black, 100 to 0; redness, a*, red to green, +60 to −60; and yellowness, b*, yellow to blue, +60 to −60) were determined. Color measurements were taken on five cookies for each recipe, at five points on each surface. The total color difference (ΔE) between the control and APP-containing cookie samples was calculated as follows:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

Free radical scavenging activities

The DPPH radical scavenging activities of the samples were measured in terms of their hydrogen donating or radical scavenging activity using stable DPPH radical. The assay was performed as previously described by Blois (Blois, 1958) with some modifications. Briefly, a 0.15 mM solution of DPPH radical in ethanol was prepared, then 5 mL of this solution was added to 1 mL of sample solution in ethanol at different concentrations, then shaken and allowed to stand for 10 min. The decolorization of DPPH-donated protons was determined by measuring the absorbance at 517 nm using a spectrophotometer (Optizen 2020 UV Plus, Mecasys Co., Ltd., Daejeon, Korea).

The spectrophotometric analysis of the $ABTS^{+}\cdot$ radical scavenging activity was determined according to the method of Re et al. (1999) with slight modifications. The $ABTS^{+}\cdot$ cation radical was generated by a reaction between 7.4 mM ABTS in H_2O and 2.6 mM potassium persulfate during storage in the dark at room temperature for 12 h. Before use, the $ABTS^{+}\cdot$ solution was diluted with methanol to obtain an absorbance of 1.1 at 734 nm. Then, 3 mL of $ABTS^{+}\cdot$ solution was added to 0.1 mL of sample. After 10 min, the percentage inhibition at 734 nm was calculated for each concentration relative to the blank absorbance. Both DPPH and $ABTS^{+}\cdot$ radical scavenging activities were calculated using the following equation:

$$\text{Radical scavenging activity (\%)} = [(Abs._{\text{control}} - Abs._{\text{sample}})/Abs._{\text{control}}] \times 100$$

Sensory evaluation

The cookies were sensory evaluated by sixty untrained volunteer panelists (26 males and 34 females, aged 20-27) drawn from the university community. The cookies were evaluated for consumer acceptance of color, flavor, chewiness, taste, and overall acceptability. The ratings were made on a 7-point hedonic scale ranging from 7- (extremely like) to 1- (extremely dislike). The order of serving was completely randomized. Overall acceptability was rated first, and another session was held to rate the remaining attributes. An interstimulus interval of 30 s was imposed between samples to allow time to recover from adaptation. Participants were instructed to rinse their palate between samples. Sufficient space was provided to handle the samples and the questionnaire, and there was no time limit on the rating. No special compensation was given to the participants. This study was approved by the Institutional Review Board of Daegu University (IRB #1040621-202203-HR-022).

Statistical analysis

The data, collected in triplicate except for color (n = 5), spread ratio (n = 8), hardness (n = 15), and sensory evaluation (n = 60), were expressed as mean and standard deviation. The results were subjected to one-way analysis of variance (ANOVA) using the general linear models (GLM) and Pearson correlation analysis. Analysis was performed using Statistical Analysis System ver. 9.4 software (SAS/STAT, Cary, NC, USA). Means were compared using Duncan's multiple range test and the significance was defined at the 5% level.

Results and Discussion

Moisture content and density of cookie dough

Table 1 describes the moisture content and density of cookie dough supplemented with different levels of APP. A progressive and significant decrease in the moisture content values of the cookie dough was observed as the amount of APP in the mixtures increased from 0 to 4% ($p<0.05$). The mean moisture content values ranged from 15.55% to 19.08% (range = 3.53%). These decreases in moisture content were probably due to the specific characteristics of the APP ingredient itself, which has a mean moisture content of 5.56%, and the higher level of APP inclusion. A similar decrease in moisture content was observed in cookie dough with persimmon leaf powder (Lim & Lee, 2016) and flaxseed flour (Kaur et al., 2019).

The density of the cookie dough appeared to increase

Table 1. Moisture content and density of cookie dough prepared from blends of wheat flour and APP[1)]

Property	APP level				
	Control	1%	2%	3%	4%
Moisture content (%, w.b.)	19.08±0.63[a,2)]	18.06±0.94[ab]	17.03±0.09[bc]	16.24±0.81[cd]	15.55±0.43[d]
Density (kg/m^3)	1.16±0.00[c]	1.19±0.02[bc]	1.20±0.23[b]	1.21±0.03[b]	1.26±0.02[a]

[1)]APP, *Artemisia princeps* leaf powder
[2)]Values represent mean±SD (n = 3). [a-d]Means with the different letters are significantly different ($p<0.05$) by Duncan's multiple range test.

slightly with the addition of APP (p<0.05); however, minor changes were observed and only the density of the control was significantly lower than APP4 (range = 0.10 kg/m^3) (p<0.05). This could be due to the interaction between cellulose in APP and wheat flour protein (Seong et al., 2017); however, the effect appears to be minimal. Others also reported a similar increase due to the incorporation of 0-4% (w/w) persimmon leaf powder (Lim & Lee, 2016) and 0-8% (w/w) pak choi powder (Lee, 2020), and their values ranged from 1.17-1.22 kg/m^3 and 1.03-1.27 kg/m^3, respectively.

Physicochemical characteristics of cookies

Data on the physicochemical properties of cookies made from blends of wheat flour and APP are presented in Table 2. The spread ratio represents how the dough is pushed outwards during the baking process, resulting in reduced thickness and increased diameter (Lee, 2020). The spread ratio has long been used to determine the cookie quality, and is a relatively complex phenomenon influenced by a variety of factors (Pareyt et al., 2009), including the type and addition of flour, fat, and sugar as well as the kneading time and method, the baking time and temperature, and so on (Koh & Noh, 1997).

The highest spread ratio of 10.01 was observed in the control sample (p<0.05). As the concentration of APP increased, the spread ratio of the cookies decreased significantly from 9.36 to 8.06 (p<0.05). This result of decrease in spread ratio supported previous work on cookies containing acai berry (Choi et al., 2014) and flaxseed powder (Kaur et al., 2017). This development could be attributed to the increase in dietary fiber with increased APP content; fiber absorbs more water during dough preparation, thus limiting dough spread and cookie diameter with a concomitant increase in thickness (Agrahar-Murugkar et al., 2015). Lower spread ratio implies better rising ability of cookies (Oladunjoye et al., 2021). The range of spread ratio is in good agreement with the reported work in previous literature (Lim & Lee, 2016; Lee, 2020).

A stepwise reduction in cookie loss rate values of cookies was observed as the amount of APP in the blends increased from 0 to 4% (p<0.05), with values are not significantly different between control and APP2 and APP2 and APP3 (p>0.05). A similar pattern of reduction was observed for cookies made with persimmon leaf powder (Lim & Lee, 2016), pak choi (Lee, 2020), and onion peel (Yeom & Hwang, 2020). This is likely due to the introduction of APP into the recipe, which resulted in prevention of moisture loss during baking through physicochemical interactions between APP and cookie dough leading to the formation of bound water and increased water holding capacity (Yeom & Hwang, 2020).

Wheat cookies had a mean hardness (16.87 N) and the addition of APP to composite cookies significantly increased the textural hardness (p<0.05). These textural changes indicated that the cookies were harder in the presence of higher levels of APP. These results of increase in the hardness could be attributed to the partial incorporation of APP with higher fiber content, which limits the expansion of the gluten dough network structure during baking, resulting in an increase in cookie hardness (Laguna et al., 2014). Previous results of increasing the hardness of wheat cookies were partially substituted with acai berry (Choi et al., 2014), persimmon leaf (Lim & Lee, 2016), pak choi (Lee, 2020), and wheat-hog plum bagasse (Oladunjoye et al., 2021) powders. The hardness values for APP cookies were found to be in the range of hardness values found by others (Lee, 2017; Lee, 2020), but lower than those reported by Lim & Lee (2016). The variation in cookie hardness may be attributed to the differences in the ingredients used and baking conditions.

Data on the color characteristics as expressed as CIELAB L*, a*, b*, and ΔE values of the cookies from the different

Table 2. Physicochemical properties of cookies prepared from blends of wheat flour and APP[1)]

Property		APP level				
		Control	1%	2%	3%	4%
Spread ratio		10.01±0.13[a,2)]	9.36±0.16[b]	8.42±0.17[c]	8.36±0.16[c]	8.06±0.14[d]
Loss rate (%)		15.90±0.98[a]	15.54±0.75[a]	14.39±0.65[b]	13.85±0.80[b]	12.58±0.76[c]
Hardness (N)		16.87±4.39[c]	19.17±3.20[c]	23.28±3.36[b]	26.35±4.79[b]	30.32±4.28[a]
Color	L*	78.38±1.07[a]	61.61±0.77[b]	56.29±0.27[c]	54.20±0.64[d]	48.56±0.66[e]
	a*	2.74±0.21[e]	3.36±0.25[d]	4.16±0.11[c]	5.95±0.26[b]	6.50±0.22[a]
	b*	21.42±0.59[ab]	21.36±0.60[ab]	22.03±0.64[a]	21.84±0.50[a]	20.73±0.51[b]
	ΔE*	-	16.78	22.14	24.40	30.06

[1)]APP, *Artemisia princeps* leaf powder

[2)]Values represent mean±SD (n = 3 for loss rate; n = 5 for color; n = 8 for spread ratio; n = 15 for hardness). [a-e]Means with the different letters are significantly different (p<0.05) by Duncan's multiple range test.

formulations are also given in Table 2. The L*, a*, b*, and ΔE values correspond to lightness, redness, yellowness, and total color difference, respectively. The effect of the addition of different levels of APP can be easily seen by observing these values of control cookies and APP-added cookies. The color parameters of the wheat cookies obtained were L* (78.38), a* (2.74), and b* (21.42). However, a stepwise and progressive decrease in L* values with APP addition from 61.61 to 48.56 was observed in composite cookies (p<0.05). Conversely, a* and ΔE values increased progressively with increasing APP levels from 3.36 to 6.50 (p<0.05) and from 16.78 to 30.06, respectively. These color changes were associated with the development of the Maillard browning reaction resulting from the interaction of reducing sugars and proteins and caramelization of sugars during baking (Usman et al., 2020). In addition, the occurrence of a higher degree of Maillard reaction with a high reddened surface is probably due to the higher protein and fiber content in APP as compared to wheat flour (Sozer et al., 2014). These results were consistent with the findings reported for cookies supplemented with different types of powders, namely onion peel (Yeom & Hwang, 2020), pak choi (Lee, 2020), and wheat-hog plum bagasse (Oladunjoye et al., 2021).

Free radical scavenging activities

The DPPH and ABTS radical scavenging activities of wheat and composite cookies, shown in Fig. 1, indicated that the control sample, which was purely wheat-based, was lower in the both activities than composite cookies containing APP. The DPPH and ABTS radical scavenging activities of wheat cookies were 5.66% and 4.90%, and the addition of APP increased the DPPH and ABTS radical scavenging activities from 6.87% to 9.37% and 5.22% to 6.39%, respectively (p<0.05). In addition, the correlation between DPPH and ABTS activities was positive and statistically significant (R^2 = 0.9497) as shown in Fig. 1. The increase in both activities with APP addition could be related to a significant amount of polyphenols present in the APP (Toda, 2004; Toda, 2005; Ruy et al., 2005; In et al., 2020). Similar increases in antioxidant activities were observed in cookies supplemented with plant-derived powders of *Stachys sieboldii* leaves (Kim & Lee, 2019), and *Houttuynia cordata* (Park, 2021).

The thermal stability of the antioxidant properties of APP or the other ingredients during baking will not be a concern for the development of value-added cookies. Previous studies showed that heat treatment of selected fruits and vegetables at different temperatures (110-150°C) for 2 h increased the DPPH and ABTS radical scavenging activities with increasing heating temperature (Kim et al., 2008). It was also reported that exposure of the standard solutions and plant extracts to high temperatures up to 100°C for 4 h showed relatively stable concentrations of phonolic compounds (Volf et al., 2014). Furthermore, Chauhan et al. (2015) reported that baking increases the antioxidant activity of cookies due to the

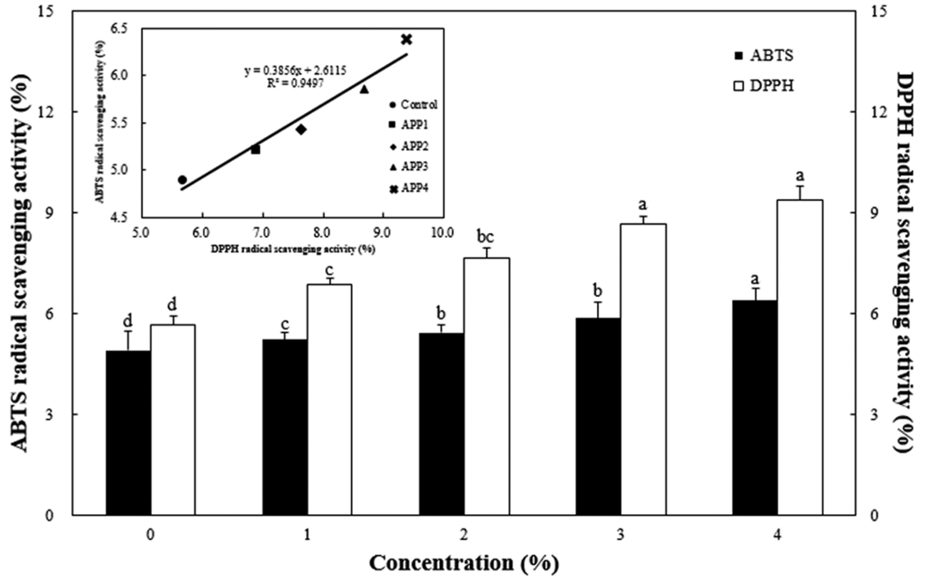

Fig. 1. DPPH and ABTS radical scavenging activities of cookies prepared from blends of wheat flour and APP and its correlation. Values are mean±SD (n = 3). Means with different letters above a bar within the same activity are significantly different at *p*<0.05.

formation of dark brown color pigments during the baking process (Chauhan et al., 2015). Thus, APP may be suitable for use as a healthy ingredient in baked cookies to enhance antioxidant content.

Sensory characteristics of cookies

Incorporation of APP in wheat flour was found to significantly influence all the sensory preference characteristics evaluated for the cookies ($p<0.05$), except for flavor preference where no significant differences were found between samples ($p>0.05$) (Table 3). The mean sensory scores of the wheat cookies (control) were 5.42 for color, 4.77 for flavor, 6.17 for chewiness, 4.62 for taste, and 5.10 for overall acceptability, respectively. The sensory panelists rated the control sample with highest score for color and chewiness. On the other hand, the highest scores for flavor, taste, and overall acceptability scores were given to cookies prepared from the blend containing 2% APP, whose scores were significantly different from those of APP3 and APP4, except for flavor ($p<0.05$). The addition of more than 2% APP in the formulation significantly reduced all the sensory preference scores of the composite cookies except for flavor. On a seven-point hedonic scale, APP2 received the highest mean scores above 4.77, except for 4.40 for the chewiness attribute, which appears to be very acceptable. The data showed that the APP cookies achieved the best improvement in sensory quality when the APP content was 2%. In view of this, the partial replacement of 2% APP in the cookie formulation seems satisfactory. In a similar study reported by Park (2021), it was found that *Houttuynia cordata* powder could be incorporated into cookies as a partial replacement of up to 2% of wheat flour without negatively affecting the physical and sensory quality.

Correlation analysis between physical and sensory characteristics of cookies

In order to clarify the relationship between physical properties and sensory attributes of cookies, Pearson correlation analysis was performed between the variables and only the significant correlated relationships are presented in Table 4. No significant correlations were found between the physical properties and most of the sensory attributes ($p>0.05$), except for chewiness. Chewiness acceptance was positively correlated with spread ratio (0.916*), loss rate (0.974**), and L* (0.933*) ($p<0.05$ or $p<0.01$), while it was negatively correlated with APP level (–0.985**), hardness (–0.980**), and a* (–0.951*) ($p<0.05$ or $p<0.01$). Consumers seemed to prefer the cookie texture in

Table 3. Consumer preferences of cookies prepared from blends of wheat flour and APP[1)]

Attribute	APP level				
	Control	1%	2%	3%	4%
Overall acceptability	5.10±1.59[a,2)]	4.87±1.26[a]	5.22±1.30[a]	4.23±1.41[b]	3.70±1.93[b]
Color	5.42±1.34[a]	4.02±0.95[c]	4.78±1.17[b]	4.55±1.55[bc]	4.15±2.13[c]
Flavor	4.77±1.53[a]	4.52±1.27[a]	4.77±1.20[a]	4.47±1.41[a]	4.43±2.17[a]
Chewiness	6.17±0.92[a]	4.90±1.12[b]	4.40±1.11[c]	3.65±1.25[d]	2.17±0.92[e]
Taste	4.62±1.44[bc]	5.03±1.18[b]	5.55±1.20[a]	4.35±1.26[c]	3.63±1.78[d]

[1)]APP, *Artemisia princeps* leaf powder
[2)]Values represent mean±SD (n = 60). [a-e]Means with the different letters are significantly different ($p<0.05$) by Duncan's multiple range test.

Table 4. Correlation between physical properties and sensory attributes of cookies prepared from blends of wheat flour and APP[1)]

	APP level	Physical properties					Sensory attributes
		Spread ratio	Loss rate	Hardness	L*	a*	Taste
APP level	1.000						
Spread ratio	–0.951*[,2)]	1.000					
Loss rate	–0.985**[,3)]	0.926*	1.000				
Hardness	0.997***[,4)]	–0.942*	–0.995***	1.000			
L*	–0.931*	0.960**	0.879*	–0.905*	1.000		
a*	0.982**	–0.898*	–0.963**	0.980**	NS	1.000	
Chewiness	–0.985**	0.916*	0.974**	–0.980**	0.933*	–0.951*	1.000
Overall acceptability	NS[5)]	NS	NS	NS	NS	–0.894*	0.903*

[1)]APP, *Artemisia princeps* leaf powder
[2)]*, Significant at $p<0.05$, [3)]**, Significant at $p<0.01$, [4)]***, Significant at $p<0.001$, [5)]NS, Not significant.

terms of chewiness when the samples were softer and lighter but less reddish in color. Among the sensory attributes, only taste was positively correlated with overall acceptability ($p<0.05$), suggesting that taste acceptance may be a dominant factor in overall acceptability. It should be noted that there was a significant positive correlation between hardness and APP level (0.997***), while hardness was inversely related to loss rate (−0.995***) ($p<0.001$). This correlation analysis confirmed the previous results.

Conclusions

The present study investigated the influence of APP addition at levels of 0-4% during cookie baking. The incorporation of APP significantly affected the physicochemical properties and consumer acceptability of cookies. Such an incorporation at different levels significantly decreased the spread ratio, loss rate, L*, and b* values, while increasing the hardness and a* values of the cookies. The consumer acceptability test showed that APP incorporation levels above 3% had a significant negative impact on consumer acceptability for most attributes except flavor. In contrast, cookies with 2% APP incorporation showed a good and satisfactory overall sensory acceptance. Thus, APP has been successfully used in cookies to improve quality and expand its potential applications in other bakery products to meet new consumer demands. Taken together, the results suggested that cookies with acceptable and satisfactory sensory acceptability and improved antioxidant activities could be produced using 2% APP as a partial replacement of wheat flour.

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