

# Physicochemical, Antioxidant and Sensory Characteristics of Cookies Incorporating Pineapple Core Powder

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## Abstract

Cookies are one of the most consumed bakery products worldwide, and efforts to enhance their nutritional profile while minimizing food waste are increasingly gaining attention. This study investigates the incorporation of pineapple core powder (PCP), an underutilized by-product rich in antioxidants, as a functional ingredient in cookie formulations. The research aims to evaluate the effects of PCP substitution at 0% (control), 20%, 50%, and 100% on antioxidant activity, physicochemical properties (moisture content, texture, colour), and sensory acceptability. The antioxidant activity, determined by the DPPH radical scavenging assay, increased significantly ( $p < 0.05$ ) with higher PCP levels, reaching 88.39% and 90.59% for the 50% and 100% formulations, respectively, compared to 34.22% in the control. Physicochemical analysis showed that increasing PCP content led to darker coloration (lower L values), increased hardness, and higher moisture content\*, which could impact shelf-life and textural characteristics. The texture profile analysis (TPA) revealed that cookies with 100% PCP were the hardest ( $6.922 \pm 0.496$  kg force), while the control exhibited the softest texture ( $3.854 \pm 0.146$  kg force), suggesting a strong correlation between fiber content and firmness. Sensory evaluation by 50 untrained panellists using a 9-point hedonic scale indicated that the 50% PCP formulation (AC50) was the most preferred, achieving the highest overall acceptability score of  $6.94 \pm 1.659$ , while the 100% PCP formulation (AC100) was rated lower due to excessive firmness and intensified bitterness. These findings highlight the potential of pineapple core powder as a sustainable, antioxidant-rich ingredient in bakery applications, offering a viable alternative for functional food development. Further research should explore the impact of PCP on shelf stability, bioactive compound retention during storage, and its interaction with other ingredients to optimize product quality and consumer acceptability.

## 1. Introduction

Cookies stand out as a popular choice, enjoyed across various demographics [11]. Recognizing the potential of cookies to meet health-promoting dietary needs, there is a rising trend toward enhancing their nutritional value through the incorporation of bioactive components. The advancement in cookie making is incorporating basic ingredients with functional properties such as pineapple core powder. The selection of quality ingredients,

notably the flour or powder utilized, plays a pivotal role in shaping the sensory appeal and overall texture of cookies.

Certain commercial brands have already created and introduced products that are fortified with antioxidants derived from a variety of fruits and vegetables, including tomatoes, asparagus, mushrooms, apples, oranges, and numerous other sources [1]. Other than that, generally, anthocyanin-rich plants are berries, including blueberry [20], cranberry [19], strawberry [7], and sweet cherry [3]. Anthocyanins have been associated with numerous health benefits, including a decreased risk of cardiovascular disease and stroke, acting as anticancer agents, exerting anti-inflammatory effects, improving vision, and enhancing cognitive function. Food industries are increasingly fortifying baked products with natural antioxidants, but the potential of underutilized fruit by-products, such as pineapple core, remains unexplored. Despite their high antioxidant content, pineapple cores are often discarded as waste. Limited studies have explored their functionality in bakery products, presenting an opportunity for developing sustainable and health-enhancing food formulations. Pineapple core, on the other hand, is known for its rich content of phenolic acids with antioxidant and anti-inflammatory activities [16]. From the previous study, the antioxidant activity for pineapple core samples obtained 33.94–41.34  $\mu\text{mol Trolox.g}^{-1}$  dry matter [15].

Pineapple is renowned for its content of bromelain, an enzyme utilized for meat tenderization, and its provision of high-quality fiber [5]. It is abundant in essential nutrients such as calcium, potassium, fiber, and vitamin C, while being low in fat and cholesterol. Moreover, pineapple serves as a rich source of vitamin B1, vitamin B6, copper, and dietary fiber. Recognized for its digestive aid properties and natural anti-inflammatory benefits, pineapple enjoys popularity as a fruit. Bromelain, a complex mixture of compounds, can be extracted from the pineapple's stem and core fruit [14]. Research suggests that certain fruit remnants may exhibit higher antioxidant activity compared to the pulp [6].

Besides that, this study aims to evaluate the effect of incorporating pineapple core powder into cookies by analysing its impact on antioxidant activity, physicochemical properties (moisture, texture, colour), and sensory attributes. It also seeks to determine the optimal substitution level that balances nutritional enhancement with consumer acceptability. Few studies have explored pineapple core powder as a functional ingredient in cookies. Such research not only explores novel uses for fruit waste but also contributes to the development of functional food ingredients. Pineapple cores, in particular, represent a substantial portion of fruit waste that often ends up discarded despite their nutritional potential [13]. Food waste poses a significant environmental and economic challenge globally. By repurposing pineapple cores into powder and incorporating them into cookie formulations, this project aims to mitigate food waste while simultaneously adding value to an otherwise underutilized by-product. This approach aligns with sustainable practices and contributes to the circular economy by transforming waste into a valuable resource. Asia has the highest percentage of pineapple waste, accounting for 46.7% of the total [18].

Converting pineapple core into powder, opens avenues for its inclusion in flavoured beverages, baked goods, and more, providing economic benefits to the industry while mitigating the environmental impact of pineapple waste disposal. The nutrients contained in the two products are known for their potential to help in the making and production of food products with highly rich nutritional values while maintaining the tastes and textures that people like to consume in food products like cookies. By thoroughly analysing the physicochemical properties, antioxidant capacity, and sensory characteristics of the resultant cookies, the investigation seeks to elucidate the feasibility of producing healthy functional cookies that cater to evolving consumer preferences and contribute to sustainable food practices. The improvement in the nutritional quality of the cookies will be analysed using sensory analysis and nutritional profiling.

## 2. Materials and Methods

### 2.1 Materials

Pineapple cores were purchased from the local market and subjected to a drying and grinding procedure. These ingredients served as the primary components for the antioxidant formulation. Additionally, other ingredients, such as all-purpose flour, butter, eggs, water, and sugar, were also sourced from the local market and utilized in the cookie preparation. The statistical tests used in the study have been specified. ANOVA was utilized to analyse variance among different formulations, and Tukey's post hoc test was applied for pairwise comparisons.

### 2.2 Preparation of Pineapple Core Powder

Pineapples (maturity index 7) were selected and purchased from a local market. Using a knife, the pineapples were sliced, and their cores washed with water before being drying. The pineapple cores will be manually sliced and grated with the grater and placed in a dehydrator set at 60°C for 6 hours, flip the other side once after 3 hours [17]. Subsequently, the dried pineapple cores will be ground into powder, cooled, and sifted through a

150 $\mu$ m mesh size sieve to obtain the desired consistency. The pineapple core powder will then be kept in airtight polyethylene packaging until required for use.

## 2.3 Formulation of Cookies With Different Levels Of Pineapple Core Powder

**Table 1** The Formulation of Cookies with different levels of pineapple core powder (g 100<sup>-1</sup>, dry basis)

Ingredients	Control	AC20	AC50	AC100
All-purpose flour	100	80	50	0
Pineapple core powder	0	20	50	100
Sugar	26	26	26	26
Shortening	60	60	60	60
Water	10.5	10.5	10.5	10.5
Egg	18	18	18	18

Note: Control (100% of all-purpose flour only), AC-20 (formulation with 20% of pineapple core powder), AC-50 (formulation with 50% of pineapple core powder), AC-100 (formulation with 100% of pineapple core powder).

## 2.4 Antioxidant analysis

The DPPH radical is commonly used to measure antioxidant ability. The colour of the solution changes from purple to yellow colour, and the intensity of colour developed is proportional to the number of moles of the stabilized molecule. A solution of DPPH was prepared by dissolving 5.9 mg of DPPH in 100 mL of methanol in a dark place. Following this, 77  $\mu$ L of the extracted sample was combined with the DPPH solution in a test tube and left for 15 minutes. Subsequently, the samples were analysed using a UV Vis Spectrophotometer (Model T60u, PG Instrument, USA) at a wavelength of 515 nm.

## 2.5 Analysis of Physicochemical Properties

### 2.5.1 Colour

Colour, a crucial visual aspect of cookies, was assessed using a Colour Spectrophotometer which STP-SPL-3003 method. Cookie samples were placed into petri dishes during measurement. The resulting metrics, including L\* (luminosity), A\* (red colour intensity), and B\* (yellow colour intensity), were measured and computed automatically. Each cookie formulation was evaluated in triplicate.

### 2.5.2 Texture

The TA.XT Plus Texture Analyzer (Double Arm) was employed to assess the hardness and fracturability of the cookies using the bend or snap method, also referred to as the three-point break technique. Compression strength was determined under specific parameters: compression test mode, pre-test speed of 1.50 mm/s, test speed of 2.00 mm/s, post-test speed of 10.00 mm/s, target mode set at distance with a distance of 15 mm, trigger force of 25 g, and data acquisition rate of 500 PPS. This analysis utilized a 3-Point Bending Rig (HDP/BSK) equipped with a blade set with knife and a HeavyDuty Platform (HDP/90). The peak force (kg) and mean distance at break (mm) were recorded. The texture assessment of the cookies was performed in triplicate using the Texture Analyzer

### 2.5.3 Moisture Content

Moisture content was determined using an AND MX-50 moisture analyzer at 140°C. Each sample (5g) was analysed in triplicate, with values recorded as the mean percentage moisture loss [4]. Most moisture analyzers employ a halogen heating lamp for this purpose [9]. The heating lamp was activated, and the sample was heated until a constant weight was achieved, indicating complete evaporation of moisture [9].

## 2.6 Selection of Panelists for sensory evaluation

Fifty untrained panellists (aged 18–35) from UTHM Pagoh were selected based on their regular cookie consumption. Samples were coded with three-digit random numbers and evaluated under controlled lighting and temperature conditions. Each panellist sampled each cookie independently without making comparisons. The sensory evaluation form included 9-point hedonic scales, and all samples were labelled with three-digit random number codes. Attributes such as colour, appearance, aroma, taste, texture, and overall acceptability were assessed using the hedonic scale [17].

### 3. Result and Discussion

#### 3.1 Antioxidant Analysis

The antioxidant activity aims to determine the presence of protein compounds that act as antioxidant compounds. The principle of this test is the reaction between pineapple core extract with 1,1-diphenyl-2-picrylhydrazyl (DPPH). DPPH is characterised as a stable free radical by the delocalisation of the spare electron over the molecule as a whole and act as a stable nitrogen-centered free radical, the colour of which changes from violet to yellow upon reduction by either the process of hydrogen- or electron-donation. Substances which can perform this reaction can be considered as antioxidants [21].

**Table 2** Results of Antioxidant activity (%) between samples

Samples	Antioxidant (DPPH)
Control	34.223 ± 0.798 <sup>c</sup>
AC20	82.200 ± 1.890 <sup>b</sup>
AC50	88.393 ± 1.099 <sup>a</sup>
AC100	90.590 ± 1.750 <sup>a</sup>

DPPH assay results showed a significant increase in antioxidant activity with higher pineapple core powder substitution. AC50 and AC100 formulations had the highest activity (88.39% and 90.59%, respectively), while the control exhibited the lowest (34.22%). These findings highlight the strong correlation between the percentage of pineapple core powder and antioxidant activity. The increase in antioxidant activity correlates with the higher content of vitamin C, bromelain, and phenolic acids in pineapple core powder. These bioactive compounds have been reported to enhance free radical scavenging capacity [2].

The determination of antioxidant activity is anticipated to demonstrate enhanced levels in formulations with these added ingredients, reflecting their potential health benefits. In the current study, pineapple core had a DPPH free radical scavenging ability as shown in Table 2 which revealed that 100% of pineapple core used had the highest DPPH radical scavenging ability. The inhibitory activity of DPPH radicals for cookies incorporating pineapple core was thought to be due to the high fiber, and phenolics and typically contains higher levels of bromelain [2]. Since the Maillard reaction is responsible for the brown pigments melanoidins during the baking process, it has been reported previously that melanoidins possess antioxidant activities [19]. Thus, Maillard reaction could contribute to the antioxidant ability of pineapple core powder cookies. The Maillard reaction, which occurs during baking, may contribute to the formation of melanoidins with antioxidant properties. This could explain the retention of antioxidant capacity even after exposure to heat [12].

#### 3.2 Physicochemical Analysis

##### 3.2.1 Colour, Texture, Moisture Content

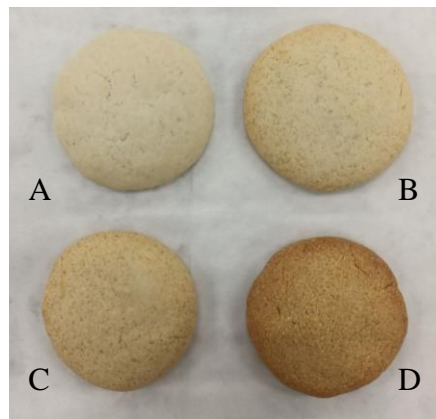
**Table 3** Results of physicochemical analysis between samples

Samples	Colour			Texture	Moisture content
	L*	a*	b*		
Control	41.220 ± 4.790 <sup>a</sup>	-0.513 ± 0.312 <sup>a</sup>	-2.037 ± 0.520 <sup>a</sup>	3.854 ± 0.146 <sup>c</sup>	8.270 ± 0.125 <sup>c</sup>
AC20	34.730 ± 0.585 <sup>a</sup>	-1.047 ± 0.230 <sup>a</sup>	-3.560 ± 0.465 <sup>a</sup>	5.681 ± 0.510 <sup>b</sup>	10.373 ± 0.359 <sup>b</sup>
AC50	34.937 ± 1.239 <sup>a</sup>	-0.703 ± 0.538 <sup>a</sup>	-3.087 ± 1.011 <sup>a</sup>	5.511 ± 0.380 <sup>b</sup>	11.623 ± 0.722 <sup>b</sup>
AC100	34.737 ± 1.009 <sup>a</sup>	-0.173 ± 0.686 <sup>a</sup>	-2.850 ± 0.995 <sup>a</sup>	6.922 ± 0.496 <sup>a</sup>	14.120 ± 0.900 <sup>a</sup>

The colour analysis of cookies with pineapple core powder, evaluated using CIE Lab parameters (L\*, a\*, b\*), showed no significant differences among the control and three formulations. The control had the highest lightness (L\*) value of 41.220 ± 4.790. L\* values decreased in formulations with pineapple core powder, indicating darker cookies. This could be attributed to the presence of carotenoids and phenolic compounds, which contribute to browning. Additionally, the Maillard reaction during baking may enhance pigment formation, affecting visual appeal. Negative a\* and b\* values across all samples indicated minimal variations in the red-green and blue-yellow spectrums. The darker hues in the formulations are likely due to pigment degradation and browning reactions such as Maillard reactions during baking, enhancing the visual appeal of cookies with pineapple core powder [12].

The texture analysis revealed significant differences in hardness among the control and formulations, measured using a Texture Analyzer. Cookies with higher pineapple core powder substitution exhibited increased hardness, likely due to fiber interactions within the dough matrix. The absence of gluten in pineapple core powder reduces water binding, leading to a denser structure [8]. Increasing pineapple core powder levels enhanced cookie hardness, but moderate inclusion levels in Formulations 1 and 2 appeared to achieve a desirable texture balance, combining firmness and consumer acceptability.

Moisture content analysis showed significant differences among the control and formulations, with values ranging from 8.270% in the control to 14.120% in Formulation 3. All samples were within the acceptable range for cookies (<14%) because the acceptable moisture content for regular cookies has been reported to be less than 14% [10]. The moisture content increased with higher pineapple core powder levels, with AC100 reaching 14.12%. This is likely due to the high fiber content, which enhances water retention, potentially affecting shelf life. Maintaining appropriate moisture levels ensures the quality and stability of the cookies during storage and consumption, highlighting the importance of precise moisture management in baked products.



**Fig. 1** Colour of four different formulation of cookies, A=Control, B=Formulation 1(AC20), C= Formulation 2(AC50), D= Formulation 3(AC100)

### 3.3 Sensory evaluation test

A sensory evaluation test utilizing a 9-point hedonic scale was conducted with 50 panellists for each of the four cookies sample formulations. The hedonic scale is designed to measure the level of preference for a product. The scale categories range from "like extremely" to "neither like nor dislike" to "dislike extremely," with multiple gradations in between. Panellists expressed their preference for each sample by selecting the appropriate category. In a sensory evaluation study of antioxidant-rich cookies featuring the incorporation of pineapple core powder, the results encompass several key aspects as the sensory characteristics evaluated during the test included colour, appearance, aroma, taste, texture, and overall acceptability. An ANOVA test was performed to determine the optimal formulation, and the results from Tukey's HSD and Post Hoc tests were used to compare the formulations and identify any significant differences based on the sensory attributes.

**Table 4** Results of sensory evaluation for 50 panellists

Samples	Colour	Appearance	Aroma	Taste	Texture	Overall acceptability
Control	5.820 ± 1.574 <sup>b</sup>	6.100 ± 1.729 <sup>b</sup>	5.400 ± 1.539 <sup>c</sup>	5.720 ± 1.885 <sup>bc</sup>	5.620 ± 1.937 <sup>b</sup>	5.880 ± 1.480 <sup>bc</sup>
AC20	6.460 ± 1.199 <sup>b</sup>	6.620 ± 1.354 <sup>ab</sup>	6.600 ± 1.485 <sup>ab</sup>	6.660 ± 1.673 <sup>ab</sup>	6.460 ± 1.644 <sup>ab</sup>	6.680 ± 1.301 <sup>ab</sup>
AC50	7.360 ± 1.191 <sup>a</sup>	7.380 ± 1.176 <sup>a</sup>	7.120 ± 1.452 <sup>a</sup>	6.740 ± 1.827 <sup>a</sup>	6.780 ± 1.799 <sup>a</sup>	6.940 ± 1.659 <sup>a</sup>
AC100	6.560 ± 1.853 <sup>b</sup>	6.400 ± 2.060 <sup>b</sup>	6.280 ± 1.841 <sup>b</sup>	5.460 ± 2.314 <sup>c</sup>	5.860 ± 2.157 <sup>ab</sup>	5.580 ± 1.928 <sup>c</sup>

The sensory evaluation of the cookies highlighted significant differences in colour preferences among the formulations. Formulation 2, which contained 50% pineapple core powder, achieved the highest mean score of  $7.360 \pm 1.191$ , demonstrating a clear preference for its vibrant golden hue. In contrast, the control, Formulation 1, and Formulation 3 showed no significant differences in colour scores, suggesting that their visual appeal was perceived as similar by the panellists. Formulation 2 emerged as the most visually appealing, achieving a mean score of  $7.380 \pm 1.176$ , significantly outperforming the control and Formulation 3. The addition of pineapple core powder in Formulation 2 contributed to its glossy and vibrant appearance. While Formulation 1 showed moderate appeal, it lacked the distinctiveness of Formulation 2. The other formulations, including the control, displayed more uniform visual characteristics, resulting in no significant differences in their appearance scores.

The enhanced aroma in AC50 may be attributed to the mild caramelization of pineapple sugars and the release of volatile compounds during baking, enhancing its sensory appeal. Formulation 1 scored moderately well but did not stand out as much as Formulation 2. The control, with no pineapple core powder, and Formulation 3, with 100% pineapple core powder, received the lowest scores, indicating less appealing aroma profiles. Taste analysis showed that Formulation 2, with a mean score of  $6.740 \pm 1.827$ , was the most favoured due to its balanced tangy flavour. Formulation 1 performed slightly lower, reflecting its improved taste compared to the control but not matching Formulation 2's appeal. Formulation 3, with its intense pineapple flavour, and the control, which lacked pineapple core powder, received the lowest scores, indicating less favourable taste profiles.

The preferred texture in AC50 ( $6.78 \pm 1.79$ ) aligns with its moderate hardness values from TPA analysis. This suggests that an optimal balance of firmness and crispness contributed to higher acceptability. Formulation 1 and Formulation 3 displayed similar texture scores, suggesting comparable appeal. The control, with no pineapple core powder, received the lowest score, indicating a less favourable texture compared to the formulations containing pineapple core powder. Formulation 2 achieved the highest score for overall acceptability at  $6.940 \pm 1.659$ , reflecting its well-balanced flavour, texture, and appearance. Formulation 1 showed good overall appeal but did not surpass Formulation 2. Despite its higher antioxidant content, AC100 was less preferred due to its harder texture and increased bitterness from phenolic compounds, which may have influenced taste perception.

#### 4. Conclusion

This study investigates the incorporation of pineapple core powder (PCP) as a functional ingredient in cookies, aiming to evaluate its effect on antioxidant activity, physicochemical properties, and sensory acceptability. Cookies were formulated with 0% (control), 20%, 50%, and 100% PCP substitution, and their nutritional and quality attributes were analysed. Results showed that antioxidant activity significantly increased ( $p < 0.05$ ) with higher PCP levels, reaching 88.39% at 50% substitution compared to 34.22% in the control. Physicochemical analysis indicated that PCP substitution led to darker coloration (lower L values), increased hardness, and higher moisture content\*, affecting texture and shelf stability. Sensory evaluation revealed that the 50% PCP formulation (AC50) was the most preferred, achieving the highest overall acceptability score ( $6.94 \pm 1.659$ ), while the 100% PCP formulation (AC100) was rated lower due to excessive firmness and bitterness. These findings suggest that 50% PCP substitution optimally balances health benefits and sensory qualities, making PCP a viable ingredient for functional bakery products. Future research should explore bioactive compound stability and shelf-life enhancement strategies for wider commercial applications.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

#### Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Wan Hadibah Wan Ab Halim, Hatijah Basri; **data collection:** Wan Hadibah Wan Ab Halim, Hatijah Basri; **analysis and interpretation of results:** Wan Hadibah Wan Ab Halim, Hatijah Basri; **draft manuscript preparation:** Wan Hadibah Wan Ab Halim, Hatijah Basri. All authors reviewed the results and approved the final version of the manuscript.*

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