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# Quality Characteristics and Nutritional Attributes of Waffles Formulated With Pineapple Byproducts as a Source of Bioactive Compounds

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**Abstract**

Pineapple peels are rich in antioxidants, vital nutrients, and other health-promoting compounds. Thus, this study aimed to prepare waffles containing pineapple peel powder and examine their functional, chemical, and nutritional quality attributes. The control waffle sample (CW) and waffles (W1, W2, and W3) by adding different ratios of pineapple peel powder (5%, 10%, and 15%, respectively by replacing it with wheat flour). Then, the chemical, physical, and organoleptic evaluations of the formulated waffles were conducted, pineapple peel powder supplementation has improved the functional quality of waffles by increasing total phenolic, flavonoid contents, carotenoids, and antioxidant activity. Four quantifiable flavonoid molecules were found in pineapple peels: daidzein, kaempferol, quercetin, and naringenin, Daidzein represents the main compound in the pineapple peels. Nine phenolic compounds were identified in the peel extracts. The main detected compounds were chlorogenic acid, gallic acid, caffeic acid, and ellagic acid. Based on the results, W3 has recorded the highest values of ash, fiber, calcium, potassium, zinc, and iron, while the control waffle sample (100% WF) had the lowest contents. W3 had the highest levels of total phenolics (630mg GAE/100g DW sample), total flavonoids (270 mg Catechin /100g DW sample), carotenoids (20.54mg/kg DW sample, and antioxidant activity as DPPH scavenging (32%), as well. Pineapple peel powder used to formulate the waffle batter resulted in a deeper color than the control waffle, which looked brilliant yellowish. According to the sensory evaluation, all samples with pineapple peel powder received 70 or higher acceptability scores for all attributes. From these results, it can be recommended that adding pineapple peel powder to the waffles to improve levels of sensor and functional properties and enrich waffles and other similar bakery products.

**Keywords:** Wheat flour; Peels fruit pineapple; Bioactive compounds; Fortified; Baked products; Sensory evaluation; Nutritional profile

## 1. Introduction

Worldwide, the yearly production of municipal solid trash is projected to be 2.01 billion tons, of which at least 33% is not managed in a way that is safe for the environment **[1].** The byproduct of cereal, fruit, and vegetables is one of the main food wastes that is continuously rising, according to **[2].** One of the greatest rates of food waste in the world is seen in fruits and vegetables, with over 45% of their produce discarded annually. The vast amounts of agricultural by-products that are discarded from the post-harvest, processing, distribution, and consumption sectors of the agricultural business might increase food waste **[3].** The byproducts from fruits and vegetables contain a notably high concentration of phenolic compounds. Polyphenols, including tannins, flavonoids, and phenolic acids in fruit and vegetable wastes, that effectively prevent oxidative stress and cell damage **[4].** Bioactive compounds, when consumed in food or supplements, offer numerous health benefits such as anti-aging effects, cardiovascular disease protection, metabolic disease control, cancer prevention, and neurodegenerative disease protection **[5].**

However, pineapple is consumed worldwide in various forms, 75% of the fruit is converted into byproducts, with pineapple peel being the largest **[6].** Pineapple peel is a valuable byproduct with high antioxidant and phenolic content, various studies have successfully utilized pineapple peel waste as a fresh and dried ingredient, adding economic value to food production, with applications in vinegar, pectin, cereal bars, yogurt, muffins, cookies, and cake **[7].** The utilization of the valuable by-products generated by the food industry in functional foods would not only benefit the environment and human health but also add value, and profitability. Consumers' positive attitudes towards these foods drive a steady increase in their production **[8].** Such compounds have been added to the formulations of new food products in response to scientific findings, offering customers, who are more concerned about their health and well-being, more natural and healthier choices **[9].**

Waffles, a wheat-based baked product with a cake-like texture, often served as bread, dessert, or a cake alternative in fast-food chains and restaurants, can be made with other flour to lower gluten content and alter texture **[10].** Owing to their ease of preparation and convenience, most ready-to-eat or quick foods are well-liked by kids, teens, and young people. These

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goods, however, are not very nutritious. They frequently lack vital nutrients and dietary fiber and are heavy in calories. It is crucial to assess and enhance the nutritional quality of food to promote better eating habits **[11].** New food products are incorporating compounds based on scientific findings to provide customers with more natural and nutritious options, responding to their health and well-being concerns. Bioactive chemicals in plant matrices have sparked interest in minimizing food waste for long-term food security [12]. Thus, the current research aims to use some underutilized materials to prepare unique functional food products with low cost and high quality. The present study was designed to assess the effects of adding different levels of pineapple peel powder (5, 10, and 15%) Wheat Flour substitution of waffles and to assess the physic-chemical properties and sensory attributes in the newly formulated waffles samples to prepare unique functional food products with low cost and high quality.

## *2.* Materials and Methods

### *2.1. Materials*

Raw materials

The peels of pineapples were obtained from the fresh pineapples (*Ananas comosus*) bought from the local market in Cairo, Egypt. Wheat flour (72% extraction) was provided by the North Cairo Flour Mills Company, Egypt. The other commodities including sunflower oil, milk, eggs, sugar, salt, baking powder, and vanilla were purchased from a local store in Cairo, Egypt.

Chemical and reagents

All the chemicals and reagents of pure analytical grade were purchased from Sigma Aldrich Co. Ltd. (Dorset, U.K.).

### *2.2. Methods*

#### *2.2.1. Preparation of pineapple peel powder*

Pineapples were washed and a sharp knife separated the peels, then cut into small pieces. The peels were dried in a conventional oven at 50°C for 48h the dried peels were ground and kept in a plastic bag until used.

#### *2.2.2. Preparation of waffles*

The method described by Huber & Schoenlechner [10] was used to prepare waffles. The control waffle batter was made using 100% wheat flour without substitution. Different pineapple peel powder proportions (5, 10, and 15%) were incorporated in the supplemented waffles (W1, W2, and W3, respectively). Table 1 lists the components of the prepared waffle samples. All the ingredients were well mixed, lifted for 5 minutes, poured, and baked into the waffle maker (Sokany KJ-108) for 3 minutes. The waffles were stored in sealed bags and kept frozen to preserve their crispiness.

**Table 1:** The composition of batter blends for waffle samples

| Ingredient (g) | Control waffle (CW) | Waffles with different percentages of pineapple peel powder | | |
|---|---|---|---|---|
| | | 5% (W1) | 10% (W2) | 15%(W3) |
| Wheat Flour (72%extraction) | 100 | 95 | 90 | 85 |
| Pineapple peel powder | 0 | 5 | 10 | 15 |
| Sugar | 15 | 15 | 15 | 15 |
| Milk | 150 | 150 | 150 | 150 |
| Sunflower Oil | 25 | 25 | 25 | 25 |
| Salt | 1 | 1 | 1 | 1 |
| Eggs | 50 | 50 | 50 | 50 |
| Baking Powder | 10 | 10 | 10 | 10 |
| Vanilla | 1 | 1 | 1 | 1 |

#### *2.2.3. Chemical analytical methods*

##### *2.2.3.1. Proximate chemical composition*

The contents of protein, fat, ash, fiber, and moisture were determined according to **A.O.A.C. [13].**

The content of carbohydrates was estimated by difference. The energy value (Kcal) was calculated theoretically according to the following equation:

$$\text{Total Energy} = [(\text{protein} \times 4)+(\text{fat}\times 9) + (\text{total carbohydrate}\times 4)].$$

##### *2.2.3.2. Determination of mineral contents*

The **A.O.A.C. [13]** method was followed to assess the mineral concentrations (Ca, Fe, K, and Zn) in wheat flour, pineapple peel powder, and waffle samples using a Flame Atomic Absorption Spectrophotometer (Model 3300, Perkin-Elmer, Beacons Field, UK) via wet digestion.

##### *2.2.3.3. Bioactive compound extraction*

According to **Singh *et al.* [14],** bioactive compounds were extracted with minor modifications. Ten grams of sample were dispensed in 100 mL of 80% ethanol and shaken for 12 hours at room temperature. Through Whatman No. 1 filter paper, the extract was filtrated, and then the filtrate was concentrated to dryness in a rotary evaporator at 37 °C and kept at 4 °C until use.

*2.2.3.4. Determination of total phenolic contents*

The total phenolics in the extract were determined using the modified Folin-Ciocalteu method described by **Makkar, & Makkar, [15].** The dissolved extract was dissolved in ethanol (1 mg/10 mL), mixed with 0.75 mL of Folin-Ciocalteu reagent, and kept for 5 min. Then 0.75 m of sodium bicarbonate (6 g/100 mL) was added to the solution. After 90 minutes at room temperature, the absorbance of the mixture at 750 nm was measured, and the total phenolic content was expressed as gallic acid equivalent per 100 g of extract.

*2.2.3.5. Determination of total flavonoids*

The total flavonoids in extracts were determined according to Chang, ***et al.*** **[16],** with minor modifications. An aliquot of 0.4 mL of extract solution was added to 4 mL of $H_2O$, and then 0.3 mL of 5% $NaNO_2$ was added. After 5 minutes, 0.3 mL of 10% $AlCl_3$ was added. After 6 minutes, 2 mL of 1M NaOH was added, and the total volume comprised 10 mL of distilled water. The absorbance of the reaction mixture (the pink color) was measured at 510nm. The content of total flavonoids was determined in milligrams (mg) of catechin equivalent (CE) per 100g of the sample using a standard curve for catechin.

*2.2.3.6. Determination of total carotenoids*

The AACC-approved technique 14–50 AACC was used to evaluate the carotenoids **[17].** For the extraction of carotenoids, an 8:2 saturated combination of n-butanol and distilled water was utilized. 1g of the material was combined with 10 mL of water-saturated butyl alcohol, mixed, and left to extract for 16 hours. After that, the extracts were filtered through the Whatman No. 1 filter paper, and the absorbance at 440nm was measured. A calibration curve using β-carotene was developed. The carotenoid content was expressed as 1g β-carotene/g sample.

*2.2.3.7. Determination of antioxidant activity (DPPH)*

The DPPH method **[18]** was employed to test the extracts' ability to scavenge free radicals, with minor changes. After vortex-mixing 0.1 mL of the sample extract with 3.9 mL of 0.25 mM DPPH in methanol, the mixture was placed in the dark for half an hour. Next, the absorbance at 515nm was measured and compared to a methanol blank that did not contain DPPH. The proportion of the DPPH radical's inhibition that the results showed was displayed. The following formula was used to get the radical scavenging activity percentage:

$\%\ inhibition = ((AB - AA)/\ AB) \times 100.$

Where the extract's absorbance was AA and the blank's absorbance was AB (95% methanol).

*2.2.3.8. Identification of polyphenols*

High-Performance Liquid chromatography (HPLC) according to Dragovic-Uzelac, et al. **[19]** was used in the analysis. With an Agilent 1260 series. 4.6 mm x 25 mm i.d., 5μm Zorbax Eclipse Plus C8 column was used for the separation. At a flow rate of 0.9 milliliters per minute, the mobile phase was composed of water (A) and 0.05% trifluoroacetic acid in acetonitrile (B). The following was the sequential programming of the mobile phase using a linear gradient: minute 0 (82% A); minute 0–1 (82% A); minute 1–11 (75% A); minute 11–18 (60% A); minute 18–22 (82% A); minute 22–24 (82% A). Monitoring of the multi-wavelength detector was placed at 280 nm. For each sample solution, the injection volume was 5 μL, and a 40 °C column temperature was maintained.

*2.2.4. Physicochemical analysis of pineapple peel powder*

*2.2.4.1. Water and oil absorption capacity (WAC and OAC)*

The modified method of Adeleke and Odedeji's **[20]** was used to calculate the WAC and OAC of pineapple peel powder. After combining one gram of the powder with ten milliliters of refined corn oil or distilled water, the tube was shaken for two minutes using a vertex mixer. The mixture was then centrifuged for 20 minutes at 4000 rpm in a pre-weighed centrifuge tube, and the supernatant was carefully decanted. To calculate the WAC and OAC values, the sample's initial weight was subtracted from the weight of the sample after the water or oil was decanted. On a dry basis, the results were recorded as grams of oil or water bound per gram of sample.

*2.2.4.2. pH measurement*

A pH meter (3510 Bench pH/ mV Meter, Jenway, UK) was used to measure the pH of the sample as described by **Lario *et al.* [21]** after mixing the sample with water at a ratio of 1:10 (w/v) at 25 °C.

*2.2.4.3. Swelling capacity*

To determine the pineapple peel powder's swelling capacity, 2.5g of the sample was precisely weighed (m) and then transferred into a calibrated tube, the volume of which was recorded (V1). 15 milliliters of distilled water were then added and mixed. After storing the sample for eighteen hours at room temperature, the final volume (V2) was determined **[22].** Ultimately, the sample's swelling capacity (mL/g) $[(V2-V1)/m) \times 100]$ was calculated, where m, V1, and V2 represent the sample's weight (g), initial volume (mL), total volume (mL), and absorbed water (mL).

*2.2.4.4. Bulk density*

A 50-measuring cylinder was filled with a 10g sample. it was tapped repeatedly on a lab bench to get the cylinder's volume to remain constant. According to **Adeleke and Odedeji [20],** the volume of the sample was determined.

Bulk density (g/cm) = Weight of Sample / Volume of sample after tapping

2.2.4.5. *Baking loss* (%)

The percent baking loss of the prepared waffles according to **Heo *et al*. [23]** was calculated as follows:

Baking loss (%) = (weight of batter−weight of sample) ×100 / weight of batter.

*2.2.4.6. Specific volume*

The weight (g) of the waffle was determined individually within one hour after baking. Specific volume was calculated according to **AACC [17],** using the following equation:

Specific volume = Volume ($cm^3$)/Weight (g).

*2.2.4.7. Hardness of waffles*

Using the Yuan and Chang method [24], the TA-XT 2 Texture meter (Texture Pro CT3 V1.2, Brookfield, Middleboro, USA) was used to measure the hardness of waffles. The force-time deformation curves were obtained by applying a 5 kg load at a cross-head spem/s.

*2.2.4.8. Color parameters*

A Hunter Lab Ultra Scan, VIS model, colorimeter (USA) was used to measure the color values of the product, such as L∗ (lightness), a∗ (red intensity), and b∗ (yellow intensity) [25]. The color values are expressed as follows: b* (-b* = blueness, +b* = yellowness), a* (-a* = greenness, +a* = redness), and L* (lightness; 0 = black, 100 = white).

*2.2.5. Organoleptic properties of waffles*

A panel of twenty panelists from Cairo University's Faculty of Agriculture's Department of Food Technology evaluated the produced waffle samples' sensory attributes. Based on a standard hedonic scale that ranges from 1 (very dislike) to 10 (extremely like), according to Meilgaard et al. [26], The panelists scored the color, taste, odor, texture, mouthfeel, and overall acceptability of the triplicates of each waffle sample. The following categories describe the total acceptability of the evaluated waffle samples: < 60, poor; 60–69, moderate; 70–79, good; 80–89, very good; >90, exceptional.

*2.2.6. Statistical analysis*

One-way analysis of variance (ANOVA) was used in the statistical computer program SPSS statistics package (Version 25) to examine the obtained data. At a probability of 5%, Duncan's multiple range test was selected to identify any significant differences between the different treatments. The results are presented as averages ± standard deviation.

## 3. Results and discussions

### *3.1. Proximate chemical composition and mineral contents of wheat flour and pineapple peel*

Mean values of proximate chemical composition and mineral contents for wheat flour and pineapple peel were determined, and the findings are shown in Table 2. From the illustrated data, it could be observed that wheat flour had higher protein and carbohydrate content levels. In contrast, it showed lower levels of ash, and fiber content than pineapple peel powder. These results are in the line of those obtained by **Romelle *et al.* and Mala *et al.* [27,7].**

**Table 2:** Chemical composition of wheat flour and pineapple peel

| Composition (%) | Wheat flour | Pineapple peel powder |
|---|---|---|
| Moisture | 11.40±0.02 | 5.07±0.12 |
| Crude fat | 3.40±0.12 | 3.26±0.01 |
| Ash | 0.60±0.15 | 3.70±0.21 |
| Crude fiber | 0.65±0.07 | 12.27±0.15 |
| Protein | 11.20±0.05 | 4.90±0.11 |
| Carbohydrates | 72.75±0.01 | 70.80±0.04 |
| | Minerals (mg/100g) | |
| Ca | 36.58±0.01 | 185.0±0.01 |
| Fe | 2.52±0.02 | 10.78±0.1 |
| K | 0.62±0.01 | 1.78±0.01 |
| Zn | 162.7±0.01 | 1680±0.2 |

Values are means of triplicates ± Standard deviation

The obtained results for the protein and fiber of wheat flour coincide with those of **El-Said, *et al.* [28]** who noted that wheat flour contents of protein and crude fiber accounted for 11.20%, and 0.65%, respectively, and close to ash content (0.53%). Moisture and protein contents in the pineapple peel were 5.07% and 4.9%, respectively. The moisture content of this study is consistent with **Aparecida Damasceno *et al.* [29],** similarly, protein content is close to that reported by **Romelle *et***

***al.* and Owoeye *et al*. [27, 30].** The Ash content in this study was 3.70%, a similar value when compared with the previous studies **[29]** but slightly lower than that of **Romelle *et al.* [27].** The fat content of flour in this study was 3.40%; these results are consistent with **Attalla, *et al.* [31]** but are not in agreement with the percentage of 1.17% reported by **Aparecida Damasceno *et al*. [29].** However, the fat content of pineapple peels (3.26%) was slightly lower than that of **Romelle *et al.* and Owoeye *et al*. [27,30].** The crude fiber content of pineapple peels in this study amounted to 12.27%; this value disagrees with the value reported by the previous studies. This value is lower than that of pineapple peel reported by **Romelle *et al.* and Aparecida Damasceno *et al.* [27,29 ],** while higher than that of **Owoeye *et al.* [30].** Table 2, also indicates that pineapple peel has carbohydrates at 70.80% (w/w). These results are close to **Morais *et al.* [32],** who denoted that the predominant composition of pineapple peel was carbohydrates. In addition, **Aparecida Damasceno *et al.* [29]** declared that carbohydrates in pineapple peel flour reached 75.63 g/100 g, and ascribed the variations in the chemical composition of pineapple peel to its cultivars and soil conditions.

According to data presented in Table 2, wheat flour is considered a poor commodity in mineral content (Ca, Fe, K, and Zn) than pineapple peel powder. The contents of calcium, iron, zinc, and potassium in pineapple peel powder in this study were 185, 10.78, 1,78, and 1680mg/100g. Ca, Fe, and K values are higher than those reported by **Sabino, *et al.* [33],** consistent with those reported for Ca by **Attalla, *et al.* [31].** Among the microelements required for the perfect growth of the microorganism are the minerals Ca, Fe, Zn, and K. Additionally, Zinc participates Zinc has an important role in antioxidant defence **[34].**

*3.2. Bioactive compound of pineapple peel powder*

The bioactive compounds and antioxidant activity of pineapple peels are recorded in Table 3. The contents of phenolics, flavonoids, and carotenoids in pineapple peels were 680 mg GAE/100g, 390 mg catechin /100g, and 49.87 mg/kg dry matter, respectively.

**Table 3:** Total phenolics, flavonoids, carotenoids, and DPPH antioxidant activity of pineapple peel powder.

| Bioactive compounds | Pineapple peel powder (M±SD) |
|---|---|
| Total phenolics | 680±0.10 mg GAE/100g |
| Total flavonoids | 390±0.10 mg catechin/100g |
| Total carotenoids | 49.87±0.53 mg/kg dry matter |
| Antioxidant activity by DPPH scavenging | 59.84±0.20 % |

Values are means of triplicates ± Standard deviation

It has been noted that flavonoids and the phenolic component appeared to be effective in inhibiting the occurrence of oxidation. Pineapple peels have a DPPH radical scavenging activity of 59.84% at a concentration of 10% pineapple peel extract, as shown in Table 3. Carotenoids and phenolic compounds may contribute to the antioxidant activity of fruits and vegetables **[35].** According to **Lasunon, *et al*. [36],** pineapple peel extract contained a high phenolic component (5803.21 mg GAE/g dry extract). Pineapple peel is a potential source of bioactive compounds including, carotene, flavonoids, and phenolic components, carotenoids, which have antioxidant activity as well as other biological activities **[37, 38].**

*3.3. Identification of phenolic compounds in pineapple peels*

HPLC-MS was used to identify and quantify the polyphenolic compounds in pineapple peels (Figure 1). The results are presented in Tables 4 and 5.

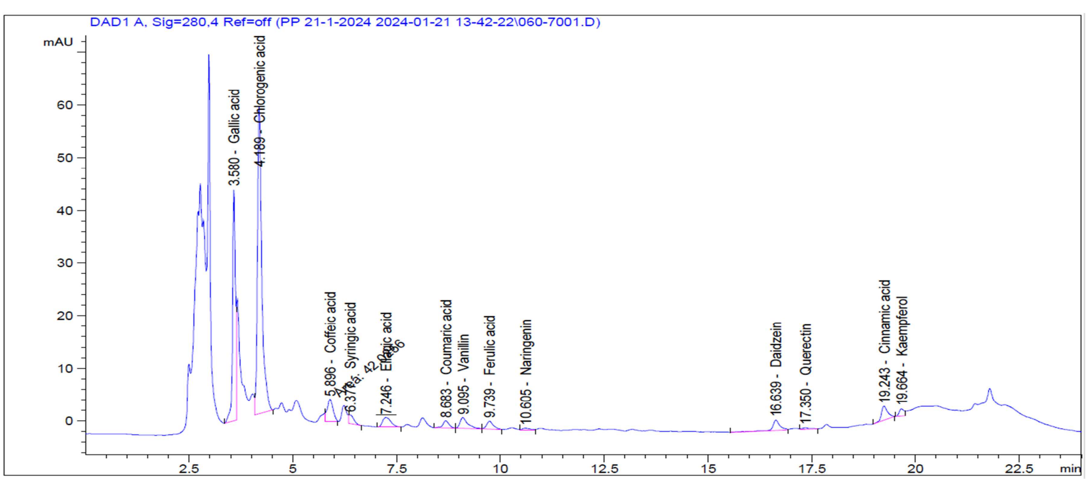


**Figure 1:** HPLC chromatogram of polyphenolic compounds in pineapple peel extract

**Table 4:** Flavonoids profile screening of pineapple peel powder

| Flavonoids | Conc. (µg/mL) | Conc. (µg/g) |
|---|---|---|
| Daidzein | 1.37 | 27.41 |
| Kaempferol | 0.70 | 14.04 |
| Quercetin | 0.54 | 10.85 |
| Naringenin | 0.40 | 7.93 |

Four quantifiable flavonoid molecules were found in pineapple peels: daidzein, kaempferol, quercetin, and naringenin, Daidzein represents the main compound in the pineapple peels (Table 4). Quercetin and kaempferol contents were high in the methanolic extract of pineapple peel as reported earlier by **Jatav, *et al.* [39].** The main polyphenolics Catechin, epicatechin, and ferulic acid were in pineapple peels **[40].** The flavonoids of pineapple are regarded as excellent antioxidants that protect cells from damage for good health by reducing the generation of free radicals **[41].**

**Table 5:** Phenols profile screening of pineapple peel powder

| Phenols | Conc. (µg/mL) | Conc. (µg/g) |
|---|---|---|
| Chlorogenic acid | 55.30 | 1105.97 |
| Gallic acid | 18.52 | 370.31 |
| Caffeic acid | 3.25 | 65.04 |
| Ellagic acid | 2.52 | 50.45 |
| Vanillin | 0.99 | 19.83 |
| Ferulic acid | 0.98 | 19.59 |
| Syringic acid | 0.96 | 19.25 |
| Coumaric acid | 0.50 | 10.01 |
| Cinnamic acid | 0.48 | 9.67 |

The details of the phenolic component profile and their quantification are displayed in Table 5. Nine phenolic compounds were identified in the peel extracts. The main detected compounds were chlorogenic acid, gallic acid, caffeic acid, and ellagic acid. Among the phenolic compounds in pineapple byproducts phenolic compounds, gallic, ferulic, and caffeic acids were found **[37].** Gallic acid, catechin, epicatechin, and ferulic acid were the main polyphenols in the pineapple skin **[39,40].** The present work presents some phenolic compounds that differ slightly from those described in the literature. This is due to the probability that different pre- and post-harvest treatments are performed on fruits and vegetables, which may influence their phenolic compound composition. The main polyphenolics in pineapple peels, according to **Li *et al.* [40],** were gallic acid, ferulic acid, catechin, and epicatechin with respective concentrations of 0.32mg/g, 0.20mg/g, 0.59 mg/g, and 0.5 mg/g. Pineapple is an excellent source of phenolic compounds and antioxidants with a higher scavenging efficacy against free radicals **[35].**

### *3.4. Functional and Physical properties of pineapple peel powder*

The Functional and Physical Properties of the pineapple peel Powder are shown in Table 6

**Table 6:** Functional and Physical properties of pineapple peel powder

| Parameters | Value (M±SD) |
|---|---|
| Water absorption capacity | 3.79±0.04 mL/g |
| Oil absorption capacity | 1.66±0.01 mL/g |
| Swelling capacity | 3.82±0.03 mL/g |
| Bulk density | 0.46±0.01 g/cm$^3$ |
| pH | 5.13±0.01 |

Values are means of triplicates ± Standard deviation

The swelling capacity and water absorption of pineapple peel powder were significantly higher than those of other fruit byproduct powders **[42].** The functional properties of peels are useful in the creation of innovative products, which are closely linked to the chemical structures of the polysaccharides and proteins in the peels, and are greatly influenced by different procedures **[43].** The data in Table 6 demonstrated that the capacities of pineapple peel powder to absorb water and oil were 3.79 mL/g and 1.66 mL/g, respectively. The water absorption capacity value in this study is similar to that of **Naseeha *et al.* [44],** but lower than that of **Mala *et al.* [7].** However, the capacity of oil absorption was marginally greater than that of **Naseeha *et al.* [44]** and slightly lower than that of Mala, et al. [7]. The swelling capacity (3.79mL/g) was lower than the previous study reported by **Naseeha *et al.* [44]** and **Dias *et al.* [43].** The bulk density of the pineapple peel powder was 0.46 g/cm, higher than those reported in other studies **[43, 44].** The pineapple peel powder presented a pH of 5.13, which is slightly higher than the value of peel powder (4.5) found by **Naseeha *et al.* [44],** and (4.6) noted by **Aparecida Damasceno *et al.* [29].** While this value was higher than that recorded by **Mala, *et al.* [7].** The differences in the pH value might be caused by variations in the cultivar, ripening condition, and storage environment of pineapple fruit **[45].**

*3.5. Proximate composition, and mineral contents of prepared waffles*

The proximate compositions and energy content (Kcal) and mineral contents (Ca, Fe, K, and Zn) of CW and fortified waffle samples with different concentrations (5, 10, and 15%) of pineapple peel powder are shown in Table 7. Initially, there was a slight, insignificant increase in the moisture content of all the supplemented samples.

**Table 7:** Proximate composition and mineral contents of control and fortified waffles with different levels of pineapple peel powder.

| Composition (%) | Samples | | | |
|---|---|---|---|---|
| | CW | W1 | W2 | W3 |
| Moisture | 2.60±0.10[a] | 2.50±0.15[a] | 2.40±0.10[a] | 2.33±0.10[a] |
| Ash | 3.08±0.01[d] | 3.16±0.02[c] | 3.70±0.05[b] | 3.87±0.03[a] |
| Fat | 20.73±0.05[a] | 20.60±0.10[a] | 20.3±0.10[b] | 20.19±0.02[b] |
| Fiber | 2.48±0.01[d] | 4.50±0.01[c] | 4.70±0.01[b] | 4.83± 0.01[a] |
| Protein | 9.60±0.01[a] | 9.31±0.02[b] | 9.05±0.03[c] | 8.93±0.22[d] |
| Carbohydrates | 61.51±0.01[a] | 59.93±0.01[b] | 59.87±0.01[bc] | 59.85±0.01[c] |
| Energy value(kcal/100g) | 471.01±0.01[a] | 462.36±0.01[b] | 458.38±0.01[c] | 424.83±0.01[d] |
| Minerals (mg/100g) | | | | |
| Ca | 39.02±0.01[d] | 39.64±0.01[c] | 39.80±0.10[b] | 43.64±0.01[a] |
| Fe | 44.99±0.06[d] | 46.32±0.01[c] | 51.51±0.01[b] | 52.07 ±0.01[a] |
| K | 213.61±0.01[d] | 224.0±0.10[c] | 252.36±0.01[b] | 254.7±0.10[a] |
| Zn | 0.19±0.01[c] | 0.23±0.01[b] | 0.24±0.01[b] | 0.49±0.01[a] |

Results are expressed as mean± SD. Values with different superscripts within the same row differ significantly (p<0.05). CW: control waffle made from 100% wheat flour, W1: waffle with 5% of pineapple peel powder, W2: waffle with 10 % pineapple peel powder W3: waffle with 15 % of pineapple peel powder.

However, data indicated that when the pineapple peel replacement levels increased, the ash and fiber contents of the fortified waffles increased ($p \leq 0.05$). The waffle sample W3 recorded the highest significant value (3.87%) of ash, while the lowest significant value (3.08%) was found for the control waffle sample. The fiber contents showed the same pattern; the control waffle sample had the lowest value (2.48 %), while all the fortified samples had greater values than the control sample, which was significantly different ($p \leq 0.05$). The obtained results for both ash and fiber are in harmony with those of **Aparecida Damasceno *et al.* [29],** who denoted those cereal bars containing pineapple peel flour had significantly higher levels of crude ash and dietary fiber. Additionally, **Naseeha *et al.* [44]** showed that pineapple peel powder used with wheat flour enhanced the nutritional value of the biscuits. The opposite trend was noticed for protein content, which decreased as the proportions of pineapple peel increased. The highest protein content was noticed in the control waffle sample, whereas all fortified samples had lower values than the control sample. The protein content of CW was 9.60. The lowest significant value of these contents (8.93) was observed in W3 containing 15% pineapple peel powder. Similar results were reported in supplemented crackers with pineapple peel powder **[27].** The fat contents showed different patterns; the fortified sample W1 and the control sample were not statistically different and had significantly higher amounts of fat than the two samples (W2 and W3). Conversely, the waffle sample used as the control showed a higher figure for the percentage of carbohydrates. On the other side, a gradual decrease in carbohydrate contents was noticed in W2, and W3 (containing 10%, and 15% pineapple peel powder, respectively) and reached 59.87%, and 59.85, against 61.51% of W1. The energy value (Kcal/ 100g) of the samples under study was shown to be slightly and gradually decreasing, being 424.83 Kcal in the waffle sample (W3) enriched with 15% pineapple peel as compared to 471.01 Kcal in the control group.

Table 7 also displays the mineral contents of the prepared waffles. The treatment W3 differed considerably from the control and other supplemented waffles (W1 and W2) in all the determined minerals. It had the highest significant values of calcium, iron, potassium, and zinc (43.64, 52.07, 254.7, and 0.49 mg/100g, respectively), followed by W2, and then W1. While the lowest value of the above-mentioned minerals (39.02, 44.99, 213.61and 0.19 mg/100g, respectively) was found for the control waffle sample, there were significant differences between it and the supplemented waffles. The substitution of wheat flour with pineapple peel significantly increased the mineral contents (Ca, Fe, K, and Zn) of the supplemented waffles since pineapple peel powder is a good source of these minerals. Similar results were reported by **El-Said, *et al.* [28]** regarding the increase in mineral content of biscuits with partial replacement of wheat flour by quinoa and chickpea flour.

*3.6. Bioactive compound of prepared waffles*

Table 8 displays the bioactive compounds, and antioxidant activity as DPPH scavenging (%) of the control and fortified waffles with different levels of pineapple peel powder.

**Table 8:** Total phenolic total flavonoids, and antioxidant activity of control waffles and fortified waffles with different levels of pineapple peel powder (on a dry weight basis)

| Bioactive component | Samples | | | |
|---|---|---|---|---|
| | CW | W1 | W2 | W3 |
| Total phenolic (mg GAE/100g DW sample) | 290±0.1[d] | 450±0.20[c] | 580±0.20[b] | 630±0.1[a] |
| Total flavonoids (mg Catechin /100g DW sample) | 140±0.1[d] | 210±0.10[c] | 230±0.20[b] | 270±0.1[a] |
| Carotenoids (mg/kg DW sample) | 10.23±0.25[d] | 16.13±0.14[c] | 18.98±0.62[b] | 20.54±0.25[a] |
| Antioxidant activity as DPPH scavenging (%) | 8.0±0.2[d] | 16.0±0.5[c] | 22.2±0.5[b] | 32.0±0.4[a] |

Results are expressed as mean± SD. Values with different superscripts within the same row differ significantly ($p<0.05$). CW: control waffle made from 100% wheat flour, W1: waffle with 5% of pineapple peel powder, W2: waffle with 10 % pineapple peel powder W3: waffle with 15 % of pineapple peel powder.

Table 8 shows the statistically significant differences among total phenolics, flavonoids, carotenoids, and antioxidant activities of the prepared waffles (control and fortified pineapple peel waffle samples with different levels). W3 had the highest levels of total phenolics (630mg GAE/100g DW sample), total flavonoids (270 mg Catechin /100g DW sample), carotenoids (20.54mg/kg DW sample, and antioxidant activity as DPPH scavenging (32%). Following it, W2, and then W1. Increasing the amount of pineapple peel replacement also substantially raised the antioxidant activity as DPPH scavenging. Conversely, CW showed the lowest levels. The corresponding values for CW were 630mg GAE/100g, 270 mg Catechin /100g, and 20.54mg carotenoids /kg DW sample. In general, the presence of substances like polyphenols, carotenoids, and chlorophyll determines the functional bioactivity of plant extract **[35].**

*3.7. Physical properties of fortified waffles*

Table 9 displays measurement results on the specific volume, baking loss, and hardness of the prepared waffles. As the substitution amount (5, 10, and 15%) with pineapple peel powder increased, the specific volume ($cm^3/g$) of the fortified waffles decreased compared to the control samples.

**Table 9:** Physical properties of control waffles and fortified waffles with different levels of pineapple peel powder

| Parameter | Samples | | | |
|---|---|---|---|---|
| | CW | W1 | W2 | W3 |
| Specific volume $cm^3/g$ | 2.2±0.01[a] | 2.1±0.01[b] | 2.1±0.01[b] | 1.9±0.01[c] |
| Baking loss % | 22.1±0.06[a] | 21.6±0.06[b] | 20.9±0.06[c] | 20.6±0.06[d] |
| Hardness N | 36.58±0.1[a] | 30.89±0.1[b] | 26.15±0.01[c] | 23.26±0.1[d] |

Results are expressed as mean± SD. Values with different superscripts within the same row differ significantly ($p<0.05$). CW: control waffle made from 100% wheat flour, W1: waffle with 5% of pineapple peel powder, W2: waffle with 10 % pineapple peel powder W3: waffle with 15 % of pineapple peel powder.

Table 9 also illustrated that the baking loss of the waffles significantly decreased as supplementation ratios increased. Formula W3 had the lowest losses (20.6%), whereas Formula CW had the greatest losses (22.1 %). While baking, several complex processes occur, with moisture loss being the main cause of loss **[46].** The larger concentration of hydroxyl groups in the fibrous structure—which tends to permit more interactions with water via hydrogen bonding—is the primary cause of the enhanced water-holding capacity of fiber-rich flours. According to **Yeom and Surh, [47],** this process is thought to be the outcome of extended gluten hydration and starch gelatinization, which is a typical occurrence when substituting gluten with fiber. One factor that determines the product's quality is its texture. Table 9 also displays the hardness of the waffle samples. There were significant differences between the hardness values of the supplemented waffles, and the control formula, CW (100% wheat flour). The control sample (CW) had the highest (36.58), whereas the sample W3 exhibited the lowest (23.26). The findings demonstrated that the hardness significantly ($P<0:05$) decreased as pineapple peel powder levels in waffles increased. Conversely, the CW (control sample) exhibited the highest hardness level. The breakdown of the gluten network contributes to the decrease of hardness **[48].** When pineapple peel powder was added to wheat flour, the starch granules were wrapped inside the gluten network structure and changed flour water absorption **[49].** The pineapple peel inclusion in crackers shows significantly increased expansion, weight loss, and surface crack while decreasing puffiness, hardness, and lightness compared to the control **[7].**

*3.8. Color measurement of prepared waffles:*

One of the key aspects of assessing foods if consumers will accept that novel foods, is color. The effect of substituting pineapple peel powder on the color of supplemented waffles is illustrated in Table 10. Based on the obtained result, the color of the control waffle sample (CW) had a significantly higher L* value than the waffle with the substitution of pineapple peel powder. The higher L* value means a lighter waffle color, indicating the yellow color of the waffle. The pineapple peel-supplemented waffle samples appeared duller compared to the control waffle. The dull color of the pineapple peel-supplemented waffles might be caused by the dark color of the pineapple peel powder. As the percentage of added powder increased, the lightness value declined, with the 15% waffle sample being the darkest with the lowest L* value (62.5), less red with the lowest a* value (2.9), and less yellow with the highest b* value (18.5). The L* of the waffle samples varied significantly. As the percentage of pineapple peel in the waffles increased, the L* decreased significantly (CW>W1>W2>W3). Both a* and b* of the waffles supplemented with pineapple peel powder (W1, W2, and W3) showed close values with no significant differences. The b* of W1 was not significantly different from that of CW but exhibited significantly higher values than those of the other supplemented samples (W2 and W3). The b* values of W2 and W3 were close, with no significant difference. So, the control waffle samples produced were yellowish, while the newly formulated waffle using different percentages of pineapple peel powder showed more intensity of color as the added powder increased to 15%. Our results coincide with **Aparecida Damasceno, *et al.* [29],** who found an insignificant difference between a* parameter values of 3% addition of pineapple peel flour in cereal bars and control, but the lightness (L*) of the samples were similar. Regarding L* and b* significant differences were observed among the treatments, thus the addition of pineapple peel flour did decrease these parameters. For the color parameter a* no significant differences were observed for the treatments when compared to the control.

**Table 10:** Color measurement of experimental waffle samples and control

| Composition (%) | Samples | | | |
|---|---|---|---|---|
| | CW | W1 | W2 | W3 |
| L* | $67.5\pm0.8^{a}$ | $66.1\pm0.1^{b}$ | $64.4\pm0.5^{c}$ | $62.5\pm0.4^{d}$ |
| a* | $2.9\pm0.3^{b}$ | $3.6\pm0.2^{a}$ | $3.9\pm0.3^{a}$ | $3.7\pm0.3^{a}$ |
| b* | $18.5\pm0.2^{a}$ | $17.7\pm0.4^{ab}$ | $16.5\pm1.1^{b}$ | $16.4\pm1.4^{b}$ |

Results are expressed as mean± SD. Values with different superscripts within the same row differ significantly (p<0.05). CW: control waffle made from 100% wheat flour, W1: waffle with 5% of pineapple peel powder, W2: waffle with 10 % pineapple peel powder W3: waffle with 15 % of pineapple peel powder. L∗ (lightness), a∗ (red intensity), and b∗ (yellow intensity)

The brown color of the pineapple peel caused a shift in the b* value of the supplemented waffle samples. According to reference **[50],** the increased total polyphenol content may be the cause of the deeper color. With the protein, glucose, fructose, and sucrose in pineapple peel, the color changes in the waffles may be related to Maillard reactions. Furthermore, exposure to heat during baking may also affect variations in lightness, due to dextrinization and caramelization **[51]. Mala *et al.* [7]** reported that cookies with a partial substitution of pineapple peel for wheat flour resulted in a notable decrease in lightness (L*). A deeper hue was seen in the crackers when more pineapple peel was added. When pineapple peel was added at 10% and 15%, there were no changes in the a*. As the percentage of pineapple peel increased, the b* value decreased.

### *3.9. Organoleptic evaluation of prepared waffles*

The sensory evaluation of pineapple peel waffles is summarized in Table 11, comparing them with the control sample. Significant differences among all the organoleptic attributes of the control sample and pineapple peel-supplemented waffle samples were found. The waffle sample (W3) with 15% pineapple peel powder recorded the lowest significant values compared to the control and other waffle supplemented samples.

**Table 11:** Effect of adding different levels of pineapple peel powder on organoleptic properties of experimental waffles and waffle control

| Composition (%) | Samples | | | |
|---|---|---|---|---|
| | CW | W1 | W2 | W3 |
| Taste | $9.3\pm0.9^{a}$ | $8.8\pm0.9^{a}$ | $8.4\pm1.1^{a}$ | $7.2\pm0.9^{b}$ |
| Texture | $9.4\pm0.8^{a}$ | $9.3\pm0.7^{a}$ | $8.1\pm0.9^{b}$ | $6.3\pm0.8^{c}$ |
| Mouth feel | $9.5\pm0.7^{a}$ | $9.0\pm0.9^{a}$ | $8.1\pm0.9^{b}$ | $6.7\pm0.8^{c}$ |
| Color | $9.8\pm0.6^{a}$ | $8.6\pm0.7^{b}$ | $7.6\pm0.7^{c}$ | $6.2\pm1.0^{d}$ |
| Odor | $9.7\pm0.7^{a}$ | $9.2\pm0.8^{a}$ | $9.1\pm0.7^{a}$ | $8.0\pm1.1^{b}$ |
| Acceptability | $9.5\pm0.6^{a}$ | $9.0\pm0.5^{b}$ | $8.2\pm0.7^{c}$ | $7.0\pm0.9^{d}$ |
| Total overall quality % | 95.33 | 89.83 | 82.5 | 69 |

Results are expressed as mean± SD. Values with different superscripts within the same row differ significantly (p<0.05). CW: control waffle made from 100% wheat flour, W1: waffle with 5% of pineapple peel powder, W2: waffle with 10 % pineapple peel powder W3: waffle with 15 % of pineapple peel powder.

Among the samples augmented with pineapple peel, the waffle with a 5% substitution received excellent scores and had the highest score for each sensory attribute. Nevertheless, the mean scores dramatically dropped as the substitute amount for pineapple peel increased. For all the organoleptic attributes of the waffle sample, W2 scored similar to W1 but significantly lower than CW. The results of the sensory assessment of color are in line with those of Hunter's color measurements. These results show that the sensory properties of waffles remain slightly affected when up to 10% substitution by pineapple peel powder. According to a previous study, adding pineapple byproducts to cookies made with partially substituted wheat flour improved both the cookies' nutritional qualities and taste. These cookies also had higher fiber content, were accepted by 97% of consumers, and had a 53% purchase intention **[52].** Cereal bars enhanced with flour derived from pineapple peels showed comparable outcomes **[29].** The items' perceived acceptability may have suffered due to the cereal bar's increased consistency as pineapple peel flour concentration increased **[29].** The results obtained correspond with the findings of **Thivani *et al.* [53],** who found that biscuits containing 5% and 10% pineapple powder received the greatest overall acceptable scores based on their sensory impression. In contrast, the improvement in color and taste of waffles refers to the yellowish color resulting from the natural pigments present in orange peels **[55].** The present results are consistent with those of Lopez-Fernandez et al. [55], who reported that all panelist groups strongly approved cookies that substituted 5%

pineapple powder. In a similar vein, **Mala et al. [7]** showed that crackers containing up to 10% pineapple peel did not differ significantly from the control; nevertheless, the panelists' preference declined and the color dramatically darkened when the amount exceeded the 10% threshold. Pineapple peel powder is an interesting ingredient for the production of bakery high nutritive value and antioxidant especially waffles prepared with 15 % pineapple peel powder incorporation had better physical and sensory properties color, taste, texture and therefore, it might be concluded that the acceptable waffles can be substituted by pineapple peel powder.

## 4. Conclusion

Incorporation of pineapple peel powder into wheat flour by different levels (5, 10, and 15%) for the production of waffles is possible based on improvement in the nutritional and functional values such as increased dietary fiber, mineral content, and natural antioxidant activities, physicochemical properties, and sensory quality emphasized differences among the samples color of waffles. The results revealed that the pineapple peel powder incorporated waffles had the highest overall quality compared to control waffles. Therefore, the 15% pineapple powder added to waffles could be significant changes in quality characteristics. This outcome would suggest using pineapple peel powder as a byproduct and enhancing the waffles as a functional food that is healthier, more nourishing, and more valuable

## 5. Conflict of interest

The authors disclosed no conflicts of interest.

## 6. References


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