https://doi.org/10.4038/tare.v26i3.5643

Tropical Agricultural Research & Extension 26 (3): 2023

RESEARCH ARTICLE

DEVELOPMENT OF COMPOSITE BISCUITS INCORPORATED WITH PINEAPPLE (*Ananas comosus*) PEEL POWDER AND EVALUATION OF THEIR QUALITY CHARACTERS

Naseeha NF, Pushparaja V and Vasantharuba S*

Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna, Sri Lanka

Received: 09 April 2023, Accepted: 01 August 2023, Published: 30 September 2023

Abstract

Pineapple peel is packed with essential nutrients, antioxidants and other healthy compounds; however, their popularity and empirical evidence related to health benefits are limited. Therefore, this study is designed to formulate pineapple peel powder incorporated composite biscuits and evaluate their quality characteristics. Initially, pineapple peel powder was prepared and its functional, chemical and nutritional evaluation were analyzed. Then biscuits were formulated by various ratios of pineapple peel powder (0%, 5%, 7%, 10% and 12%) and organoleptic evaluation was conducted. Based on the findings from sensory evaluation studies 7% and 10% pineapple peel powder incorporated biscuits were selected for further studies: physical, chemical and nutritional evaluation, along with control. According to the findings, biscuits formulated with pineapple peel powder had better antioxidant properties and higher crude fiber, ash, sugar, potassium and ascorbic acid contents than control biscuits. Moreover, 10% peel powder incorporated biscuit was selected as the best blend ratio using results obtained by nutritional and sensory analysis. Additionally, storage studies showed that these biscuits can be stored for 60 days without microbial spoilage. The present study recommended pineapple peel powder enriched biscuits may be a better alternative product based on the results.

Keywords: Pineapple peel powder, Biscuit, Nutritional profile, Quality characters, Sensory character

INTRODUCTION

The most prominent fruit on earth and a member of the *Bromeliaceae* family is the pineapple (*Ananas comosus* L). Across the world, it can be grown in the tropical and subtropical climate zones (Dhar *et al*. 2008). It is a well-known fruit due to its appealing sensory and nutritional properties, containing vitamins, minerals, protein, carbohydrates, fiber, flavonoids and carotenoids. Moreover, pineapple is one of the most popular fruit crop farmed in Sri Lanka. According to the statistics of the Department of Agriculture, Sri Lanka, Mauritius and Kew are the most popular pineapple varieties cultivated in Sri Lanka, while Mauritius being the most widely grown. In Sri Lanka, pineapple is consumed either as raw or processed products such as jam, juices, jellies, puree, powder and nectar (Thivani *et al*. 2016).

Pineapple peel is the main by-product of the fruit comprising around 34.7% of the whole fruit (Huang *et al*. 2011). Moreover, pineapple peel has been investigated as a functional nutritional supplement of dietary fiber, mainly insoluble fiber, protein, polyphenols or antioxidant compounds, vitamins and essential minerals. Based on human health, fibers reduce the risk of diabetes, gallstone formation, colonic cancer, issues related to obesity and atherosclerosis. The pineapple peel powder added advanced scientific features to the products, including lower pH and moisture content and increased acidity, which contrib-

*Corresponding author: seeva@univ.jfn.ac.lk

uted to the product's microbiological quality. These outcomes are quite acceptable, because these factors directly contribute to the keeping quality of the product (Aparecida Damasceno *et al*. 2016).

The bakery industry is rapidly expanding, and its products are becoming more popular among individuals from every part of the world. Biscuits have several appealing characteristics among ready-to-eat snacks. They are stapled foods with benefits such as ready-to-eat form, widespread consumption, long shelf life and high eating quality. Also, it is widely accepted and consumed by nearly all consumer profiles in many countries, making them a useful dietary supplement for nutritional improvement (Arshad *et al*. 2007). Additionally, the utilization of by-products from fruits and vegetables in bakery products is considered as an innovative approach, owing to the presence of their antioxidant, anti-carcinogenic and anti-inflammatory properties (Thivani *et al*. 2016).

Moreover, several previous research studies have focused on developing value added products by utilizing waste materials such as peels, bagasse and seeds as rich sources of essential nutrients. These studies explored various aspects, including the effects of Bordeaux grape pomace (*Vitis labrusca* L.) on the antioxidant and total phenolic content of cookies (Karnopp *et al*. 2015), the use of orange pomace in the formulation of gluten-free bread (O'Shea *et al.* 2015), the nutrient profile of cookies with guava peel, formulation of blends powder using banana peel (Martins *et al.* 2019), and the development of cereal bars containing pineapple peel flour (Aparecida Damasceno *et al.* 2016). However, only limited studies were conducted to investigate the physical, functional, nutritional and sensory analysis of bakery products incorporated with pineapple peel powder by-products.

On this background, the pineapple peel powder incorporated into bakery products is considered as the most effective way to produce healthy value added food items using edible by-products and also their recovery would be economically feasible. Therefore, the objective of this study was to develop pineapple peel powder incorporated biscuits and to assess the proximate composition, physicochemical properties, sensory attributes and antioxidant properties of the formulated biscuits.

MATERIALS AND METHODS

Materials

Evenly ripen pineapple peels of Mauritius variety were collected from the local juice bar located in Kilinochchi, Sri Lanka. Peels were collected hygienically and stored in the refrigerator for further usage (maximum 1 day). Other ingredients such as wheat flour, sugar, baking powder, margarine and corn flour were procured from a shop in Kilinochchi.

Preparation of Pineapple Peel Powder

Pineapple peel powder was prepared with slight modification using the method described by Aparecida Damasceno *et al.* (2016). Accurately weighed 2.76 kg of peel was washed thoroughly using clean water for 2 to 3 times to remove any unwanted materials. Then the peels were sanitized with 200 ppm sodium hypochlorite solution for 15 minutes to prevent contamination from pesticides and chemicals. Peels were washed again using clean water and cut into small pieces (2 cm x 2 cm). These small pieces of peels were dried using a cabinet dryer at 60° C for 18 hours. After drying, the peels were ground by using a blender, and then it was sieved using 100 μm stainless sieve to obtain the pineapple peel powder. Finally, it was stored in glass bottles under refrigerated conditions until further use.

Preparation of Biscuits

In order to formulate the pineapple peel powder incorporated biscuits, pineapple peel powder was used to partially substitute the wheat flour dough mixture. Five treatment biscuits were formulated by adding varying amounts of pineapple peel powder to a control biscuit (T1), which was prepared with 45 g wheat flour, 3.2 g corn flour, 25 g margarine, 25 g sugar, 1.8 g baking powder and water. Different proportions of pineapple peel powder as 5%, 7%, 10% and 12% were added to the dough mixture respectively, to make different pineapple peel powder incorporated composite biscuits T2, T3, T4 and T5.

Pineapple peel powder biscuits were prepared using the creamery method with some modifications (Man *et al.* 2014). The weighed ingredients were added and mixed to form the dough. The dough was kneaded on a flat working bench, and it was rolled into a sheet and cut with a round cutter. The cut pieces of dough were placed into a greased oven tray and baked for 9 minutes at 180° C in a preheated oven. Finally, the composite biscuits were packed in airtight polyethylene bags and stored in a desiccator.

Sensory Evaluation

The samples were subjected to sensory analysis to evaluate consumer preference using the 5-point hedonic scale with 35 semi trained panelists. Samples were labeled with 3-digit numbers and presented to the panelist with plain water. Sensory attributes of samples: appearance, texture, color, flavor, taste and overall acceptability were evaluated.

Analysis of Functional Properties

The functional properties which include water and oil absorption capacity and bulk density were analyzed by method as indicated in Oladunjoye *et al*. (2021), with some modifications, while the swelling capacity was analyzed using the modified method by Siti Faridah *et al*. (2021). Water absorption capacity was estimated as a percentage of water absorbed by the powder while oil absorption capacity was calculated as a percentage of oil absorbed by the powder.

Analysis of Physical Properties

Physical properties of the control and the two most preferred pineapple peel powder incorporated composite biscuits from the sensory analysis were evaluated. Initially, the selected biscuits were analyzed for diameter, thickness, weight, spread factor, bulk density and water activity by following the respective procedures described in Oladunjoye *et al.* (2021). All measurements were carried out in duplicates. The diameter and the thickness of the biscuits were measured using a vernier caliper in millimeters. Spread factor of biscuits was determined using diameter to thickness ratio of each biscuit. The weight of biscuit was measured using an analytical balance.

Analysis of Chemical Properties

pH

The pH of the pineapple peel powder, control and selected composite biscuits samples were evaluated by following procedures. One gram of powder and biscuit samples were taken into test tubes. Then, 10 mL of distilled water was added to each tube and it was stirred. Finally, the pH of the sample was measured using a calibrated pH meter.

Titratable Acidity

Titratable acidity of the pineapple peel powder, control and selected composite biscuits samples were evaluated by following procedures. A sample of one gram was dissolved with 10 mL of distilled water and filtered. The filtrate was titrated with 0.1 N NaOH, using 2 drops of phenolphthalein as an indicator. The percentage of acidity was calculated using the following equation.

$$\text{Percentage of total acidity} = 0.1 \times \text{volume of NaOH (L)} \times 192.43 \div (3 \times \text{weight of sample}) \times 100 \quad \textbf{....Eqn 01}$$

Ascorbic acid (Vitamin C)

Ascorbic acid content of the pineapple peel powder, control and selected composite biscuits samples were evaluated by the reducing action of ascorbic acid on the blue dyestuff 2,6 - dichlorophenol indophenol as described in Khan *et al*. (2013). The ascorbic acid content was calculated as mg per 100 g/100 mL of the sample.

Proximate Analysis

Proximate analysis was performed for pineapple peel powder, control and selected composite biscuits to compare the nutritional value of each biscuit. Moisture (oven drying method), dry matter content, ash (incineration method), total sugar, protein (Kjeldahl method), fat (continuous extraction method), crude fiber (Ankom technology), carbohydrate (percentage differences) and potassium content (flame photometric method) were analyzed by following procedures as stated in

Nielsen (2010). All the analyses were carried out in duplicates.

Analysis of Antioxidant Properties

Analysis of antioxidant properties of the pineapple peel powder, control and selected composite biscuits samples was performed using following procedures. Total phenolic content present in the samples was analyzed by Folin-ciocalteu method indicated by Noreen *et al.* (2017). The absorbance of the developed color was measured at 765 nm using UV-Visible spectrophotometer (UH5300 spectrophotometer, HITACHI, Japan). The total phenolic content was determined using the standard curve and stated in terms of mg Gallic acid equivalent (mg GAE) per gram of dry matter.

The estimation of total flavonoid contents was done by following Aluminium chloride colorimetric method as described in Zou *et al.* (2004) with some alterations. The reaction mixture was mixed and absorbance was measured at 510 nm using a UV-Visible spectrophotometer. The flavonoid content was indicated in terms of mg Catechin equivalent (mg CE) per gram of dry matter.

Total antioxidant capacity of the sample was determined using the colorimetric method stated by Prieto *et al.* (1999). The absorbance was measured at 695 nm against a blank using a UV-Visible spectrophotometer. The antioxidant capacity was calculated using a standard curve of ascorbic acid and expressed as mg Ascorbic acid equivalent antioxidant capacity (AAE) per gram of dry matter.

Shelf-life Study of Control and Composite Biscuits

Freshly prepared control and selected composite biscuit samples were packed in a polyethylene bag and stored in ambient temperature storage conditions ($30 \pm 2^{\circ}$ C). Microbial and Visual analyses were performed at 30 days intervals up to 60 days after storage. The total plate count and yeast and mold count were analyzed using procedures described in Oladunjoye *et al.* (2021).

Statistical Analysis

Sensory evaluation results were analyzed using SPSS statistics (V.20) with 95% confidence interval. Functional, physical, chemical and antioxidant properties were analyzed using a Completely Randomized Design (CRD) using the SAS statistical package. The significant difference was compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Sensory Results of Prepared Biscuits

Pineapple peel powder incorporated biscuits were developed using different treatments such as T1 (Control), T2 (5%), T3 (7%), T4 (10%) and T5 (12%). According to the formulations, biscuits were prepared and sensory analysis was done using 5-point hedonic scale with 35 semi trained panelists. Mean values of analyzed sensory attributes of biscuits prepared by partially substituting wheat flour with different percentages of pineapple peel powder are stated in Table 1. A significant difference ($p<0.05$) was observed among the samples for all the tested sensory attributes.

Moreover, highest mean values for all the sensory attributes were observed in T3 and T4 and the least mean value was observed for color and flavor in the control sample. Similarly, a previous study indicated 5% and 10% pineapple powder incorporated biscuits had the highest overall acceptable scores based on their sensory perception (Thivani *et al.* 2016). Additionally, higher mean scores were observed for T3, T4 and T2 for the attributes of taste. However, the overall acceptability of the T3 and T4 got higher mean values. According to the sensory analysis, T3 and T4 composite biscuit samples were selected and further analyses were carried out. The outcomes are closely connected with the presence of texture, flavor and aroma enhancing components in pineapple peel powder.

Functional and Chemical Properties of Pineapple Peel Powder

The functional attributes of powders have an advantageous role in the production of novel products. The chemical structure of polysaccharides and proteins in peels is highly correlated with their functional properties, which

Table 1: Mean value for sensory attributes of control and composite biscuits

	T1 (Control)	T2 (5%)	T3 (7%)	T4 (10%)	T5 (12%)
Appearance	3.74 ± 0.53^{bc}	3.63 ± 0.42^{b}	4.28 ± 0.39^{c}	3.84 ± 0.56^{c}	3.06 ± 0.49^{a}
Texture	3.71 ± 0.36^{b}	3.82 ± 0.51^{bc}	3.98 ± 0.24^{c}	3.93 ± 0.42^{c}	3.09 ± 0.22^{a}
Color	2.72 ± 0.29^{a}	3.96 ± 0.56^{c}	4.09 ± 0.63^{c}	3.97 ± 0.69^{c}	3.2 ± 0.62^{b}
Flavor	2.89 ± 0.45^{a}	4.08 ± 0.64^{c}	4.17 ± 0.27^{c}	4.15 ± 0.51^{c}	3.04 ± 0.54^{b}
Taste	3.82 ± 0.32^{b}	3.96 ± 0.62^{b}	4.01 ± 0.39^{b}	3.97 ± 0.58^{b}	2.64 ± 0.56^{a}
Overall acceptability	3.53 ± 0.44^{b}	3.45 ± 0.51^{b}	4.12 ± 0.38^{c}	4.09 ± 0.48^{c}	3.14 ± 0.47^{a}

Mean ± SD values with different letters of superscripts in the same row are significantly different.

are greatly influenced by milling, thermal processing extrusion cooking, and so on (Dias *et al*. 2020). The findings of functional properties of pineapple peel powder are displayed in Table 2. The bulk density was 0.29 gcm^{-3} while the capacities for water absorption, oil absorption and swelling were 3.95 mL/g, 0.75 mL/g, 4.39 mL/g and respectively.

Bulk density of the pineapple peel powder obtained from this study was lower value than the value of bulk density (0.39 ± 0.01) in another study (Dias *et al.* 2020). Similarly, water absorption capacity, oil absorption capacity and swelling capacity of this study were lower than the previous study. In which the values of pineapple peel powder were 4.3 ± 0.29, 1.9 ± 0.08 and 7.57 ± 0.29 respectively. The particle size and initial moisture level have an impact on the bulk density. The presence of high bulk density indicates that they are excellent for application in diet preparation while, the formulation of complementary foods would benefit from low bulk density (Chandra and Samsher 2013).

Additionally, the water absorption capacity and swelling capacity of the pineapple powder were higher than that of wheat flour (Chandra and Samsher 2013) who reported that water absorption capacity and swelling capacity of the wheat flour were 1.4 and 0.17 mL/g respectively. However, the oil absorption capacity of the pineapple flour had lower value than wheat flour (1.46 mL/g). Another study stated that the oil absorption capacity of wheat flour was 0.725 mL/g (Shad *et al*. 2013), which is lower than the oil absorption capacity of pineapple peel powder. The maximum value of water absorption capacity helps to prevent water loss while applying external stress, and also high oil absorption capacity value is potentially useful in flavor retention, enhancing the palatability and extending the shelf life of bakery products (Dias *et al*. 2020).

In this study, the pineapple peel powder presented lower pH (4.5 ± 0.05) which is closer to the value of peel powder (4.6 ± 0.02) found in Aparecida Damasceno *et al*. (2016), but this value is higher than that of same variety (3.85 ± 0.01) found by Kodagoda and Marap-

Table 2: Functional and chemical properties of pineapple peel powder at room temperature

Parameters	Value
Water absorption capacity (mL/g)	3.95 ± 0.21
Oil absorption (mL/g)	0.75 ± 0.07
Swelling capacity (mL/g)	4.39 ± 0.04
Bulk density (g cm^{-3})	0.29 ± 0.06
pH	4.5 ± 0.05
Titratable acidity (citric acid %)	1.4 ± 0.11

Values represents Mean ± standard deviation of duplicate determinations.

ana (2017). The changes in the pH value are highly correlated to the ripening stage of the pineapples. The low pH of the sample tested in this study indicates that there is a low risk to product will degrade due to microbes, enzymes, or non-enzymatic reactions. Titratable acidity of the flour was 1.4 ± 0.11%. However, the titratable acidity of pineapple fruit is 0.6 to 1.62 percent in Kodagoda and Marapana (2017). This range may be due to differences in pineapple fruit ripening state, pineapple cultivar and storage atmosphere.

Nutrient Profile of Pineapple Peel Powder

The nutrient profile of the pineapple powder is shown in Table 3. Moisture content and protein in the peel were 6.81 ± 0.20% and 3.6 ± 0.31% respectively. Moisture value of this study is similar to the value studied by Aparecida Damasceno *et al*. (2016), and also protein content is similar to the value (3.52 ± 0.21%) reported by Kodagoda and Marapana (2017) for the same variety (Mauritius).

Fat content of flour was lower in this study (0.33 ± 0.01%), but this value is not in agreement with the percentage of 1.17 ± 0.08 reported by Aparecida Damasceno *et al.* (2016). Ash content of this study was 4.53 ± 0.03%, a similar value when compared with the previous studies (Kodagoda and Marapana 2017) and (Aparecida Damasceno *et al.* 2016). The crude fiber content of this study was high (20.87 ± 0.36%), this value is in disagreement with the value (4.92 ± 0.5%) as reported by previous study (Aparecida Damasceno *et al.*

Table 3: Nutrient profile of pineapple peel powder

Parameters	Value
Moisture (%)	6.81 ± 0.20
Ash (g/100 g)	4.53 ± 0.03
Crude Protein (g/100 g)	3.6 ± 0.31
Fat (g/100 g)	0.33 ± 0.01
Crude fiber (g/100 g)	20.87 ± 0.36
Carbohydrate (g/100 g)	63.88 ± 0.31
Reducing sugar (g/100 g)	0.25 ± 0.01
Non reducing sugar (g/100 g)	1.23 ± 0.01
Total sugar (g/100 g)	1.48 ± 0.01
Ascorbic acid (mg/100 g)	4.89 ± 0.04
Potassium (mg/100 g)	89.1 ± 0.85
Total phenolic content (mg GAE/100 g)	46 ± 0.71
Flavonoid (mg CE/100 g)	74.5 ± 0.12
Antioxidant capacity (mg AAE/100 g)	96.23 ± 0.45

Value represents Mean ± standard deviation of triplicate determination.

2016). But this value is lower than the peel of the same variety of pineapple (42.02 ± 1.07) (Kodagoda and Marapana 2017).

Potassium content of this study was 89.1 ± 0.85 mg/100 g, which is lower than the value reported as 398.08 ± 15.23 mg/100 g in previous research study (Kodagoda and Marapana 2017). Lower mineral content may be depending on several factors, including variety, maturity stage, texture and conditions of soil and type and rate of irrigation, which can cause variations in micro and macro mineral content in varieties of fruits (Leterme *et al*. 2006). Carbohydrate content of this study was 63.88 ± 0.31%, which contrasts with findings reported by Huang *et al*. (2011) who found pineapple peel has lower carbohydrate content of 42.3%. It is considered as a significant point to state the differences in the physicochemical composition of pineapple peel powder from different cultivars and soil conditions (Aparecida Damasceno *et al*. 2016).

Ascorbic content of this study was 4.89 ± 0.04% which is a lower value than 6.3 ± 0.06% reported by Dos Santos et al. (2020). Total sugar content and reducing sugar (RS) content of the flour of present study were very low (1.48 ± 0.00% and 0.25 ± 0.01%) compared with values (18.3 ± 0.00% and 3.0 ± 0.2%) found by Dos Santos *et al.* (2020) for the pineapple peel. During fruit maturation, starch is hydrolyzed into glucose and fructose, which indicates the peel has a lower RS content (Cao *et al.* 2013).

Total phenolic, flavonoid and antioxidant content of this study were 46 ± 0.71 mg GAE, 74.5 ± 0.12 mg CE and 96.23 ± 0.45 mg AAE / 100 g of dry matter, which were higher compared with the previous study by Li *et al.* (2014), who have found total phenolic content, flavonoid and antioxidant capacity of peel is 31.76 mg GAE and 58.51 mg CE and 3.7 mg/ 100 g of dry matter. The presence of antioxidants helps to extend the shelf life of bakery products and maintain their freshness and flavor over time (Czajkowska–González *et al.* 2021).

Physical and Chemical Properties of Control and Composite Biscuits

Physical and chemical properties of control and composite biscuits are shown in Table 4. The results showed no significant difference in weight, diameter and thickness of the biscuit samples. However, there was a significant difference ($p<0.05$) between the control and composite biscuit samples for bulk density ranging from 0.33 - 0.36 gcm^{-3}. Bulk density increased with the addition of pineapple peel powder, but no significant difference between composite samples. Moreover, a significant difference ($p<0.05$) was observed in the spread ratio of composite biscuits (Ahmad *et al.* 2016).

For the pH, a significant difference was observed between the control and composite biscuit samples, but no significant difference among the composite biscuit samples. This indicates that the pineapple peel flour addition

Table 4: Physical and chemical properties control and composite biscuits

Parameters	Control (0%)	T3 (7%)	T4 (10%)
Weight	5.07 ± 0.02^{a}	5.53 ± 0.24^{a}	5.18 ± 0.26^{a}
Bulk Density (gcm^{-3})	0.33 ± 0.01^{b}	0.35 ± 0.00^{a}	0.36 ± 0.00^{a}
Diameter (cm)	4.2 ± 0.07^{a}	4.26 ± 0.07^{a}	4.15 ± 0.07^{a}
Thickness (cm)	0.44 ± 0.01^{a}	0.42 ± 0.01^{a}	0.44 ± 0.01^{a}
Spread ratio	9.43 ± 0.14^{b}	10.24 ± 0.00^{a}	9.55 ± 0.32^{b}
pH	6.78 ± 0.02^{a}	6.4 ± 0.03^{b}	6.38 ± 0.16^{b}
Titratable acidity (Citric acid %)	0.26 ± 0.01^{c}	0.51 ± 0.01^{b}	0.64 ± 0.01^{a}

Mean ± SD values with different letters of superscripts in the same row are significantly different.

reduces the pH with increasing its titratable acidity.

Nutrient Profile of Control and Composite Biscuits

Results of the nutrient profile of biscuits are presented in Table 5. No significant difference was observed between the samples for crude protein, crude fat and carbohydrate. Crude fiber of composite biscuits ranged from 9.25% - 10.19% and control samples contained lower amounts than the pineapple incorporated biscuits. This signifies the pineapple peel powder rich in fiber.

Ash, moisture, reducing sugar, potassium and ascorbic acid contents are increased with increasing the level of pineapple peel powder. Total sugar content of pineapple peel powder incorporated biscuits ranged from 11.68% - 12.52%, a significant difference was observed between control and composite samples ($p<0.05$), this indicating that pineapple peel contains a significant amount of total sugar.
There was a significant difference in antioxidant properties: total phenolic content, flavonoid content and antioxidant capacity for all samples. During the baking process, pineapple peel powder can release conjugated phenolic acids, leading to substantial increase in the amount of total phenolic content and antioxidant capacity of baked products, such as biscuits. Additionally, the Maillard reaction, caramelization and phenol oxidation may also contribute to an increase in total antioxidant compounds in foods (Ragaee *et al*. 2014).

Shelf-life of Control and Composite Biscuits

Visual analysis and microbial count were evaluated in the 30 days interval up to 60 days after storage of control and composite biscuits packed in the normal packaging material (polyethylene) under room temperature condition ($30 \pm 0.5^{\circ}$ C) , and its results are shown in Table 6. In the visual analysis, color, flavor and crispiness of the control and composite samples were remaining unchanged for up to two months of storage period.
Microbial tests are vital in assessing the shelf life of food products as they identify the microorganisms responsible for food spoilage.

Table 5: Nutrient profile of control and composite biscuits

Parameters	Control (0%)	T3 (7%)	T4 (10%)
Moisture (%)	2.11 ± 0.02^{c}	2.45 ± 0.01^{b}	2.83 ± 0.06^{a}
Ash (g/100 g)	1.46 ± 0.00^{c}	1.82 ± 0.02^{b}	1.92 ± 0.04^{a}
Crude Protein (g/100 g)	5.92 ± 0.06^{a}	6.05 ± 0.06^{a}	6.13 ± 0.06^{a}
Fat (g/100 g)	13.37 ± 0.5^{a}	14.28 ± 0.02^{a}	15.52 ± 0.4^{a}
Crude fiber (g/100 g)	7.82 ± 0.23^{b}	9.25 ± 0.09^{a}	10.19 ± 0.56^{a}
Carbohydrate (g/100 g)	69.3 ± 1.99^{a}	66.2 ± 2.10^{a}	63.47 ± 1.36^{a}
Reducing sugar (g/100 g)	0.03 ± 0.02^{c}	0.14 ± 0.02^{b}	0.23 ± 0.02^{a}
Non reducing sugar (g/100 g)	1.25 ± 0.04^{b}	1.33 ± 0.01^{a}	1.23 ± 0.01^{c}
Total sugar (g/100 g)	10.42 ± 0.06^{b}	11.68 ± 0.01^{a}	12.52 ± 0.00^{a}
Ascorbic acid (mg/100 g)	1.33 ± 0.13^{c}	3.7 ± 0.03^{b}	4.92 ± 0.01^{a}
Potassium (mg/100 g)	21.78 ± 0.72^{c}	35.27 ± 0.68^{b}	42.48 ± 0.01^{a}
Total phenolic content (mg GAE/100 g)	58.23 ± 0.55^{c}	185.15 ± 2.9^{b}	198.4 ± 1.13^{a}
Flavonoid (mg CE/100 g)	257 ± 1.41^{c}	391 ± 1.41^{b}	422 ± 2.83^{a}
Antioxidant capacity (mg AAE/100 g)	191.5 ± 2.12^{c}	274.1 ± 1.56^{b}	281 ± 1.41^{a}

Data presented mean ± SD values with different letters of superscripts in the same row are significantly different.

Table 6: Total plate count and yeast and mold count of control and composite biscuits under room storage condition

Samples	Storage period (Days)	Total plate count (CFU/g)	Yeast and mold (CFU/g)
Control (100% wheat flour)	0 days	-	-
	30 days	4.09×10^{1}	-
	60 days	5.09×10^{1}	-
T3(7%)	0 days	-	-
	30 days	2.09×10^{1}	-
	60 days	2.81×10^{1}	-
T4 (10%)	0 days	-	-
	30 days	2.09×10^{1}	-
	60 days	2.68×10^{1}	-

According to the specification for biscuits (Sri Lanka standard 256:2010), aerobic plate count should be below 1 x 10^3 CFU/g. During the storage period, total plate count was slightly increased in both control and composite biscuits up to 60 days of storage period but not exceeding the limitation level. Yeast and mold growth was not observed in all samples. In this study, the microbial count results were satisfied by both control and composite biscuits during storage for two months of period at room temperature.

CONCLUSIONS

This study found that the development of biscuits from pineapple peel powder had a considerable effect on the nutritional and health benefits. The present study revealed that 7% and 10% pineapple peel powder incorporated biscuits were preferred among the other samples according to the sensory analysis. Based on the nutritional analysis, 10% incorporated biscuit was selected as the best formulation. Moreover, this finding indicated that biscuits produced from pineapple peel powder contain a sufficient amount of ash, crude fiber, sugar, potassium and ascorbic acid. In the nutrient analysis, the values of ash, sugar, potassium and ascorbic acid were significantly increased with an increasing amount of pineapple peel powder.

Moreover, the results of the antioxidant analysis indicated a significant difference between the control and composite biscuits, since pineapple peel powder contains a significant amount of antioxidant properties. Additionally, shelf life study of biscuit samples was giving better sensory attributes without microbial spoilage during two months period. Finally, the present study created new knowledge on the formulation of novel edible products using pineapple peel powder.

ACKNOWLEDGMENT

The authors would like to acknowledge Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna, Sri Lanka for providing the necessary facilities to conduct this research study.

AUTHOR CONTRIBUTION

Naseeha NF: Investigation and writing draft, Pushparaja V: Writing original and editing and Vasantharuba S: Conceptualization, writing-review, editing and project administration.

REFERENCES

Ahmad M, Wani TA, Wani SM, Masoodi FA and Gani A 2016 Incorporation of carrot pomace powder in wheat flour: effect on flour, dough and cookie characteristics. Journal of Food Science and Technology, 53: 3715 - 3724, viewed 11 January 2023, <https://doi.org/10.1007/s13197-016-2345-2>

Aparecida Damasceno K, Alvarenga Gonçalves CA, Dos Santos Pereira G, Lacerda Costa L, Bastianello Campagnol PC, Leal De Almeida P and Arantes-Pereira L, 2016 Development of Cereal Bars Containing Pineapple Peel Flour (Ananas comosus L Merril). Journal of Food Quality, 39: 417 - 424, viewed 21 January 2023, <https://doi.org/10.1111/jfq.12222>

Arshad MU, Anjum FM and Zahoor T 2007 Nutritional assessment of cookies supplemented with defatted wheat germ. Food chemistry, 102: 123 - 128, viewed 02 February 2023, <https://doi.org/10.1016/j.foodchem.2006.04.040>

Cao S, Yang Z and Zheng Y 2013 Sugar metabolism in relation to chilling tolerance of loquat fruit. Food Chemistry, 136: 139 - 143, viewed 18 January 2023, <https://doi.org/10.1016/j.foodchem.2012.07.113>

Chandra S and Samsher 2013. Assessment of functional properties of different flours. African Journal of Agricultural Research, 8: 4849 - 4852, <https://doi.org/10.5897/AJAR2013.6905>

Czajkowska–González YA, Alvarez–Parrilla E, del Rocío Martínez–Ruiz N, Vázquez –Flores AA, Gaytán–Martínez M and de la Rosa LA 2021 Addition of phenolic compounds to bread: antioxidant benefits and impact on food structure and sensory characteristics. Food Production, Processing and Nutrition, 3, viewed 27 January 2023, s43014-021-00068-8>

Dhar M, Rahman SM and Sayem SM 2008 Maturity and post harvest study of pineapple with quality and shelf life under red soil. International Journal of Sustainable Crop Production, 3: 69 - 75.

Dias PGI, Sajiwanie JWA, Rathnayaka RMUSK 2020 Chemical Composition, Physicochemical and Technological Properties of Selected Fruit Peels as a Potential Food Source. International Journal of Fruit Science, 20: S240 - S251, viewed 17 December 2022, <https://doi.org/10.1080/15538362.2020.1717402>

Dos Santos BA, Teixeira F, Soares JM, Do Amaral LA, De Souza GHO, De Almeida TSF, Schiessel DL, Dos Santos EF and Novello D 2020 Pineapple Jam Physicochemical and Sensory Evaluation With Added Pineapple Peel, International Journal of Research - GRANTHAALAYAH, 8: 374 - 383, <https://doi.org/10.29121/granthaalayah.v8.i7.2020.438>

Huang YL, Chow CJ and Fang YJ 2011 Preparation and physicochemical properties of fiber-rich fraction from pineapple peels as a potential ingredient. Journal of Food and Drug Analysis, 19: 318 - 323, viewed 05 February 2023, <https://doi.org/10.38212/2224-6614.2179>

Karnopp AR, Figueroa AM, Los PR, Teles JC, Simões DRS, Barana AC, Kubiaki FT, Oliveira JGB and Granato D 2015 Effects of whole-wheat flour and bordeaux grape pomace (*Vitis labrusca* L.) on the sensory, physicochemical and functional properties of cookies. Food Science Technology, 35: 750 - 756, viewed 25 January 2023, <https://doi.org/10.1590/1678-457X.0010>

Khan I, Azam A and Mahmood A 2013 The impact of enhanced atmospheric carbon dioxide on yield, proximate composition, elemental concentration, fatty acid and vitamin C contents of tomato (*Lycopersicon esculentum)*. Environmental Monitoring and Assessment, 185: 205 - 214, <https://doi.org/10.1007/s10661-012-2544-x>

Kodagoda K and Marapana R 2017 Development of non-alcoholic wines from the wastes of Mauritius pineapple variety and its physicochemical properties. Journal of Pharmacognosy and Phytochemistry, 6: 492 - 497.

Leterme P, Buldgen A, Estrada F and Londoño AM 2006 Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia. Food Chemistry, 95: 644 - 652, viewed 14 January 2023, <https://doi.org/10.1016/j.foodchem.2005.02.003>

Li T, Shen P, Liu W, Liu C, Liang R, Yan N and Chen J 2014 Major polyphenolics in pineapple peels and their antioxidant interactions. International Journal of Food

Properties, 17: 1805 - 1817, <https://doi.org/10.1080/10942912.2012.732168>

Man S, Muste S and Adriana P 2014 Preparation and Quality Evaluation of Gluten-Free Biscuits. Bulletin UASVM Food Science and Technology, 71, <https://doi.org/10.15835/buasvmen-fst>

Martins ANA, Pasquali MAB, Schnorr CE, Martins JJA, de Araújo GT and Rocha APT 2019 Development and characterization of blends formulated with banana peel and banana pulp for the production of blends powders rich in antioxidant properties. Journal of Food Science Technology, 56: 5289 - 5297, <https://doi.org/10.1007/s13197-019-03999-w>

Nielsen SS 2010 Food Analysis Laboratory Manual. Springer, New York, <https://doi.org/10.1007/978-1-4419-1463-7>

Noreen H, Semmar N, Farman M and McCullagh JSO 2017 Measurement of total phenolic content and antioxidant activity of aerial parts of medicinal plant *Coronopus didymus*. Asian Pacific Journal of Tropical Medicine, 10: 792 - 801, viewed 01 March 2023, <https://doi.org/10.1016/j.apjtm.2017.07.024>

O'Shea N, Rößle C, Arendt E and Gallagher E 2015 Modelling the effects of orange pomace using response surface design for gluten-free bread baking. Food Chemistry, 166: 223 - 230, <https://doi.org/10.1016/j.foodchem.2014.05.157>

Oladunjoye AO, Eziama SC and Aderibigbe OR 2021 Proximate composition, physical, sensory and microbial properties of wheat-hog plum bagasse composite cookies. Lebensmittel-Wissenschaft & Technologie, 141, viewed 11 February 2023, <https://doi.org/10.1016/j.lwt.2021.111038>

Prieto P, Pineda M and Aguilar M 1999 Spectrophotometric quantitation of antioxidant capacity through the formation of a Phosphomolybdenum Complex. Analytical Biochemistry, 269: 337 - 341, <https://doi.org/10.1037/a0037168>

Ragaee S, Seetharaman K and Abdel-Aal ESM 2014 The Impact of Milling and Thermal Processing on Phenolic Compounds in Cereal Grains. Critical Reviews in Food Science and Nutrition, viewed 23 January 2023, <https://doi.org/10.1080/10408398.2011.610906>

Shad MA, Nawaz H, Noor M, Ahmad HB, Hussain M and Choudhry MA 2013 Functional properties of maize flour and its blends with wheat flour: Optimization of preparation conditions by response surface methodology. Pakistan Journal of Botany, 45: 2027 - 2035.

Siti Faridah MA, Nur Atikah MRL, Jau-Shya L, Hasmadi M, Mohd Rosni S, Wolyna P and Noorakmar AW 2021 Physicochemical and thermal properties of durian seed flour from three varieties of durian native of Sabah. Food Research, 5: 374 - 381, viewed 16 January 2023, <https://doi.org/10.26656/fr.2017.5(4).659>

Thivani M, Mahendran T and Kanimoly M 2016 Study on the physico-chemical properties, sensory attributes and shelf life of pineapple powder incorporated biscuits. Ruhuna Journal of Science, 7: 32 - 42, viewed 18 February 2023, <https://doi.org/10.4038/rjs.v7i2.17>

Zou Y, Lu Y and Wei D 2004 Antioxidant activity of a flavonoid-rich extract of *Hypericum perforatum* L. in vitro. Journal of Agriculture and Food Chemistry, 52: 5032 - 5039, viewed 27 January 2023, <https://doi.org/10.1021/jf049571r>