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Dr. Maya T

Pineapple Research Station,
Kerala Agricultural
University, Vazhakulam,
Kerala, India

Anunayana KR

Pineapple Research Station,
Kerala Agricultural
University, Vazhakulam,
Kerala, India

Rukzana Basheer

Pineapple Research Station,
Kerala Agricultural
University, Vazhakulam,
Kerala, India

Rini Mohan

Pineapple Research Station,
Kerala Agricultural
University, Vazhakulam,
Kerala, India

Corresponding Author:

Dr. Maya T

Pineapple Research Station,
Kerala Agricultural
University, Vazhakulam,
Kerala, India

Valorisation of pineapple pomace powder as a functional ingredient in cookie fortification

Maya T, Anunayana KR, Rukzana Basheer and Rini Mohan

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Abstract

The pineapple industry is a significant contributor to the global fruit market, generating substantial amounts of waste, including peels, cores, and pomace. Effective utilisation of this waste can mitigate environmental impacts and create new revenue streams. This study examines the potential of pineapple pomace powder as a value-added ingredient in the bakery industry, with a focus on its application in cookie production. The pineapple pomace powder obtained was rich in carbohydrates (35.25 g) and crude fibre (17.86%). Cookies enriched with pineapple pomace powder baked at 140 °C for 35 minutes produced cookies with a fine, crispy texture with delicate pineapple flavour and were found microbiologically stable for 90 days. This study revealed that refined wheat flour can be fortified with 10.8% pineapple pomace powder to prepare functional cookies without compromising sensory properties and microbiological safety.

Keywords: Pineapple pomace powder, valorisation, functional cookie, fortification

1. Introduction

Pineapple (*Ananas comosus* (L.) Merr. Bromeliaceae) is one of the most popular tropical fruits in the global market. Industrial processing of pineapple produces a large amount of fruit biowaste, mainly consisting of peel (30%), pomace (50%), core (7%), and crown (13%), which accounts for about 25-35% of the fruit's total weight (Banerjee *et al.*, 2018) [4]. Selani *et al.*, 2014 [22], have reported that because these untreated fruit biowaste are improperly disposed of, as they lack a specific destination. However, these biowastes have significant potential to be recycled into raw materials or converted into valuable, higher-grade products (Abdullah *et al.*, 2020) [1]. Valorising pineapple by-products offers a sustainable approach aligned with circular economic principles, opening promising opportunities for innovation and economic development in the food industry (Jose *et al.*, 2022) [15].

The bakery industry is an essential part of the food sector, offering a diverse selection of convenient and functional foods tailored for health-conscious consumers. Cookies are ready-to-eat baked products valued for their sensory appeal, ease of eating, affordability, and potential for nutritional enhancement through the addition of functional ingredients (Jose *et al.*, 2022) [16]. They are made using a formulation high in sugar and fat (shortening) and contain very little water. Unlike bread and cakes, their low moisture level reduces the risk of microbial growth, allowing them to have a longer shelf life (Hanan, 2013) [11]. The main flour used in cookie production is typically wheat or composite flour, which forms the base ingredient in many baked goods, including bread, cakes, rolls, and pastries (Giwa and Ikujenlola, 2010) [9]. However, refined or bleached flours widely used in commercial baking have been linked to potential long-term health risks. Some researchers have called these refined flours "slow poisons" because of their low nutritional value and possible negative metabolic effects from chronic use. The high gluten content and calorie density of wheat flour have raised nutritional and health concerns, leading researchers to explore indigenous and underutilized flours as viable alternatives to partially or fully replace wheat flour in food formulations (Bello *et al.*, 2022) [5]. Adjusting the standard recipe by adding functional ingredients like dietary fibre, alternative grains, and fat replacers has resulted in biscuits with improved nutritional quality and functional properties (Handa *et al.*, 2012; Yadav *et al.*, 2012) [12, 24].

Pineapple pomace, the fibrous residue left after juice extraction, is a significant by-product of pineapple processing and is high in dietary fibre, approximately $45.22 \pm 3.62\%$, with 98.18% being insoluble. This makes it a promising functional ingredient for high-fibre food formulations. Adding pineapple pomace powder to cookie recipes can boost their nutritional quality by increasing dietary fibre and providing beneficial techno-functional properties. The high water-holding capacity (WHC) and oil-binding capacity of the fibers can improve dough handling, reduce spread during baking, and contribute to desirable textures like chewiness and crispness. Additionally, these properties can help retain moisture and enhance the sensory acceptance of the final product (Elleuch *et al.*, 2011) [6]. Foods rich in dietary fibre typically have a low glycemic index, leading to a slower and more controlled rise in blood glucose and insulin after eating, while also supporting weight management and lowering Low Density Lipoprotein (LDL) cholesterol levels.

2. Materials and Methods

2.1 Procurement of raw materials

Fresh fruits of 'Vazhakulam Pineapple', food-grade citric acid and potassium metabisulphite (KMS), refined wheat flour, sugar, butter, salt, and baking powder were sourced from the local market.

2.2 Preparation of pineapple pomace powder (PPP)

Fresh fruits were peeled and pomace was obtained immediately after juice extraction. Pineapple pomace was cabinet air dried at 60 °C for 24 hours after 10 minutes pretreatment with 0.5% citric acid and 0.3% potassium metabisulphite (KMS). Dried pomace was pulverised to fine powder in a household mixer grinder (Panasonic), sieved, and stored in HDPE container at ambient conditions for cookies preparation.

2.3 Assessment of physicochemical characteristics of PPP

Physico-chemical properties, moisture (%), mineral (%), calcium (%), crude fibre (%) and total carbohydrates(%) of the dried PPP were estimated as per Ranganna (1991) [20] and mean value of 3 determinations were estimated.

2.4 Optimisation of baking parameters

Preliminary experiments were conducted to optimise microwave baking temperature and duration to achieve uniform baking and the desired cookie texture (Table 1). Due to the high fibre and sugar content of pineapple pomace flour, cookies were baked at 140, 150, and 160 °C to allow gradual moisture removal while preventing excessive browning and quality deterioration. University, Gwalior (Madhya Pradesh), to study the effect of different.

Table 1: Baking parameters for PPP fortified cookies

Treatments	Temperature (°C)	Duration (min)
B1	140	35
B2	150	15
B3	150	18
B4	160	20

2.5 Development of PPP fortified cookies

Pineapple pomace powder (PPP) was blended with refined wheat flour at predetermined proportions for fortification. The ingredient compositions of the different treatments are furnished in Table 2. Butter and powdered sugar, weighed accurately, were manually creamed until a light and fluffy consistency was obtained. The fortified flour was mixed with baking powder and incorporated into the creamed mixture. The dough was kneaded to achieve a plastic, non-sticky consistency and portioned into uniform sizes, which were baked at 150 °C for 18 minutes in a preheated convection microwave oven. The different formulations of cookies were organoleptically analysed for color, texture, flavour and overall acceptability using a 5-point Hedonic scale as described by Ranganna (1991) [20].

Table 2: Ingredient proportions for pineapple pomace fortified cookies

Treatments	Refined wheat flour (g)	Pineapple pomace powder (g)	Sugar (g)	Butter (g)	Baking powder (g)
S0 (control)	46	0	18	35	1
S5	41	5	18	35	1
S10	36	10	18	35	1
S15	31	15	18	35	1
S20	26	20	18	35	1

After baking, the cookies were cooled on a wire rack and organoleptically tested. The best product based on organoleptic score was packed in aluminium laminate pouches and stored for 120 days at room temperature.

2.6 Assessment of microbial quality of PPP fortified cookies

The microbial safety of developed functional cookies was monitored for 120 days of storage at room temperature. The pour plate method (Ikechukwu *et al.*, 2017) [19] was employed with minor modifications. One gram of cookie sample was homogenized in 10 ml sterile peptone water and serially diluted. From each dilution, 1 ml aliquots were transferred to sterile petri dishes and overlaid with ~15 ml molten nutrient agar, mixed thoroughly, and incubated at 38 °C for 24 h to determine total viable counts (CFU/g). For yeast and mould enumeration, aliquots were pour-plated

with molten Sabouraud Dextrose Agar (SDA) and Potato Dextrose Agar (PDA) supplemented with antibiotics and incubated at ambient temperature for 3 days and colony counts were recorded.

2.7 Statistical Analysis

The statistical analysis was carried out using the 'GRAPES' (R-shiny Based Analysis Platform Empowered by Statistics) software (Gopinath *et al.*, 2020) [10].

3. Results and Discussion

3.1 Physico-chemical properties of Pineapple Pomace Powder (PPP)

The pineapple pomace powder recorded a moisture content of 6.72%, which is well below the critical limit for microbial growth and enzymatic activity (Croguennec and Jeantet *et al.*, 2016) [14]. Such low moisture ensures better

storage stability and longer shelf life. The crude fibre content was 17.86%, reflecting the fibrous nature of pomace residues rich in cell wall components (Table 3).

Table 3: Physico-chemical properties of pineapple pomace powder

SL No	Properties	Content per 100 g of PPP
1	Moisture content (%)	6.72 ± 0.16
2	Total Carbohydrates (g/100 g)	35.25 ± 0.22
3	Crude fibre (%)	17.86 ± 0.12
4	Total Mineral Contents (%)	3.24 ± 0.08
5	Calcium (mg/100 g)	16.20 ± 0.02

*The values are represented as mean ± standard deviation



Fig 1: Pineapple Pomace Powder [PPP]

This high fibre level justifies its use as a potential dietary fibre supplement for functional food applications (JA Larrauri., 1999) ^[17]. The total carbohydrate content (35.25%) indicates the presence of residual sugars and polysaccharides, which contribute to the nutritive value of the powder (Huang *et al.*, 2021) ^[13]. The total mineral content (3.24%) represents appreciable mineral matter, while the calcium level (16.20 mg/100 g), though modest, contributes to the overall mineral profile. The analytical results demonstrate that pineapple pomace powder is a low moisture, fibre-rich material (Figure 1).

3.2 Optimisation of baking conditions for cookies

Cookies were baked at different temperature-time combinations to determine optimal conditions. Baking at 140 °C for 35 minutes (B1) produced cookies with a fine, crispy texture, indicating complete baking and uniform moisture removal. Baking at 150 °C for 15 minutes and 150 °C for 18 minutes resulted in under baked cookies, and a soft texture. Increasing the temperature to 160 °C for 20 minutes (B4) led to rapid surface browning, limited uniform heat transfer and slightly moist core (Table 4). These observations demonstrate that both temperature and baking time are critical parameters for achieving desirable cookie quality. (Šarić *et al.*, 2017) ^[21]. Based on these trials, 140 °C for 35 minutes was selected as the optimal baking

condition (Figure 2).

Table 4: Effect of baking parameters on development of PPP fortified cookies

Treatments	Observation
B1	Fine, crispy, fully baked
B2	Moist core
B3	Slightly undercooked
B4	Surface caramelization, slightly moist core



Fig 2: Pineapple peel powder fortified functional cookies

3.3 Effect of PPP fortification on sensory attributes of cookies

The sensory evaluation of cookie samples (Figure 3) indicated that cookies without PPP (S0) and composite flour with PPP (S5) had satisfactory scores across all sensory attributes. Incorporation of pineapple pomace powder (PPP) at 10.8% in refined wheat flour provided optimal functional enrichment while maintaining desirable texture, colour, odour, and flavour. Higher levels of PPP (S10, S15, and S20) produced a harder texture, reduced spread, and a slightly vegetative odour, resulting in lower sensory scores and rejection by the panelists. The increased dietary fibre content and residual fruit components at higher fortification levels may have adversely affected the texture, flavour, and aroma of the cookies, leading to a decline in sensory acceptability. Accordingly, only S0 and S5 (Figure 3) were acceptable in terms of appearance, colour, flavour, texture, and overall sensory quality. Refined wheat flour with pineapple pomace powder at levels of 10.8% or lower can be used to prepare functional cookies without adversely affecting consumer-preferred sensory attributes.

3.4 Microbial quality of PPP fortified cookies

The total microbial count serves as an indicator of a food's production, storage, and handling conditions, and can be used to estimate its shelf life and quality retention. (Ikechukwu *et al.*, 2017) ^[19]. Microbial analysis on the first day of cookie production showed no bacterial growth on Nutrient Agar and no detectable yeast or mould growth on Potato Dextrose Agar and Sabouraud Dextrose Agar. The microbiological integrity remained unchanged during the three-month storage duration (Table 5).

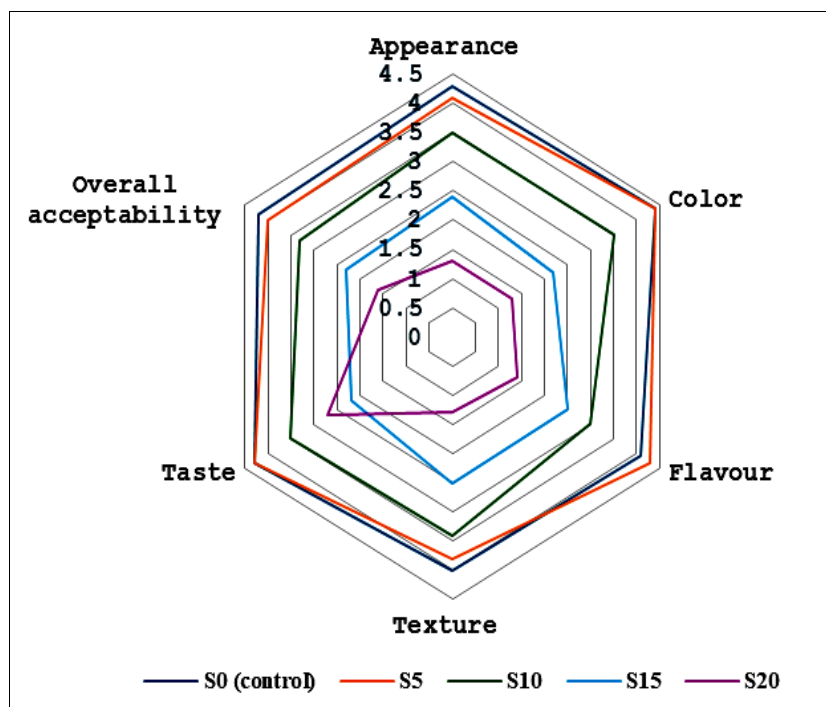


Fig 3: Organoleptic scores of PPP fortified cookies

Table 5: Microbial quality evaluation of PPP fortified cookies

Storage period	Total plate count (CFU g ⁻¹)	Yeast & mould (CFU g ⁻¹)
0 Month	0×10 ⁴	0×10 ³
1 Month	0×10 ⁴	0×10 ³
2 Months	0×10 ⁴	0×10 ³
3 Months	0×10 ⁴	0×10 ³
4 Months	2.3 ± 0.2×10 ⁴	0×10 ³

The values are represented as mean ± standard deviation

It was reported that the maximum bacteria (aerobic) plate count for cookies is 5.30×10^4 CFU/g and, 5.0×10^3 CFU/g for mould counts (Allen *et al.*, 2004). This could also be due to the dry nature of the cookie samples (Ezeama, 2007) [8]. Bacteria usually require at least 0.91 water activity (aw) and fungi require at least 0.7aw, while below 0.6 aw microorganisms cannot be able to survive (Croguennec and Jeantet *et al.*, 2016) [14].

4. Conclusion

The study demonstrates the potential of utilising pineapple pomace powder as a value-added ingredient in cookie production, offering a promising solution for reducing food waste and enhancing product nutrition. Refined wheat flour fortified with 10.8% pineapple pomace powder can be used to prepare functional cookies without compromising sensory properties and microbiological safety. This approach promotes sustainability, pineapple fruit waste valorisation, and the development of innovative, nutrient-enriched bakery products.

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