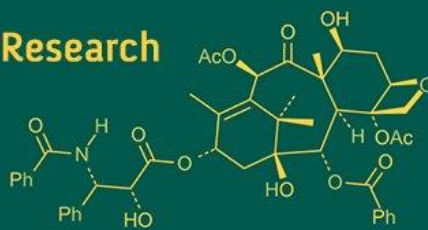


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Physio-chemical property of value-added cookies with partial replacement of wheat flour by fruit pomace flour

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Abstract

This study investigated the formulation, quality evaluation, and ambient storage stability of value-added cookies prepared by partially replacing wheat flour with apple pomace flour (APF) and pineapple pomace flour (PPF). Four experimental treatments were evaluated: T_0 (100% wheat flour control), T_1 (80% WF + 10% APF + 10% PPF), T_2 (70% WF + 15% APF + 15% PPF), and T_3 (60% WF + 20% APF + 20% PPF). The developed cookies were packaged in high-density polyethylene (HDPE) and stored under ambient conditions for 120 days to evaluate changes in physico-chemical characteristics at 30-day intervals. The incorporation of fruit pomace flours significantly improved the nutritional profile of the cookies at Day 0, increasing dietary fibre (from 1.12% in T_0 to 3.83% in T_3), ash content (0.98% to 1.81%), protein content (7.33% to 7.96%), and fat content (21.74% to 23.22%). Conversely, pH decreased from 7.03 in T_0 to 6.00 in T_3 . Over the 120-day ambient storage period, moisture content increased significantly across all treatments (T_0 : 2.45% to 3.23%; T_3 : 2.96% to 3.63%), while slight reductions were recorded in ash, protein, fat, dietary fibre, pH, and carbohydrate levels ($p \leq 0.01$). The results demonstrate that replacing up to 30-40% of wheat flour with equal blends of apple and pineapple pomace flour produces nutrient-dense, fibre-enriched cookies with acceptable quality during 120 days of ambient storage in HDPE packaging.

Keywords: Apple pomace flour, pineapple pomace flour, composite flour, value-added cookies, storage stability, physico-chemical properties

1. Introduction

Fruit processing industries generate substantial quantities of solid by-products, primarily in the form of pomace, peels, and seeds. Apple (*Malus domestica*) and pineapple (*Ananas comosus*) processing for juice extraction yields up to 25-35% and 40-50% of the raw fruit weight as pomace, respectively [1, 2]. Disposal of fruit pomace presents severe environmental challenges and economic burdens if unmanaged. However, these by-products are rich sources of dietary fiber, minerals, bio-active phenolics, and natural organic acids [3, 4]. Converting fruit pomace into dried pomace flour presents a sustainable strategy for waste valorization and functional food formulation [5]. Bakery products, particularly cookies and biscuits, are widely consumed snack foods due to their long shelf-life, convenience, and affordability [6]. Standard commercial cookies are typically manufactured from refined wheat flour, which is high in digestible carbohydrates but low in dietary fiber and micronutrients [7]. Partial replacement of refined wheat flour with fruit pomace flour offers an effective route to enhance the nutritional value of bakery products [8, 9]. This investigation evaluates the physico-chemical property of value-added cookies formulated by blending wheat flour with apple and pineapple pomace flours. and 120-day ambient storage.

2. Materials and Methods

2.1 Raw Material Preparation

Fresh, mature apples and pineapples were procured from the local market in Meerut, UP, India. The fruits were thoroughly washed with running tap water to eliminate adhering dust and soil particles. Juicing was performed to separate the juice from the pomace. The fresh pomace was blanched at 85 °C for 2 min to inactivate endogenous enzymes [10]. Blanched pomace was dried in a tray dryer at 60 °C for 10-12 h until the moisture content dropped to

approximately 5%. The dried pomace was ground using an electric grinder, sieved through a 60-mesh screen to yield fine Apple Pomace Flour (APF) and Pineapple Pomace Flour (PPF), and stored in airtight glass jars under ambient conditions. Other bakery ingredients—wheat flour (WF), baking powder, refined vegetable oil, granulated sugar, and High-Density Polyethylene (HDPE) film—were purchased locally.

2.2 Formulation and Cookie Processing

Cookies were developed using the creaming method according to four treatment combinations:

- T_0 (Control): 100% Wheat Flour
- T_1 : 80% WF + 10% APF + 10% PPF
- T_2 : 70% WF + 15% APF + 15% PPF
- T_3 : 60% WF + 20% APF + 20% PPF

The basic formulation per 100 g flour blend contained 45 g edible vegetable oil, 60 g powdered sugar, and 1.25 g baking powder. Vegetable oil and sugar were creamed together in a whipping machine for 2 min at medium speed. Sieved flours and baking powder were folded into the cream and kneaded with water to form a uniform dough. The dough was rolled to a standard thickness, cut into circular

shapes using a cookie cutter, and baked in a deck oven at 180 °C for 18 min. After cooling on wire racks at room temperature, the cookies were sealed in HDPE polythene pouches and stored at ambient temperature for 120 days.

2.3 Analytical Measurements

- **Physico-Chemical Properties:** Moisture content was determined gravimetrically by hot-air oven drying at 105 °C [15]. Total ash was determined using a muffle furnace (Sandeep Instruments) at 550 °C [16]. Crude protein ($N \times 6.25$) was analyzed using an automated Kjeldahl digestion and distillation system (Kjelplus-KES20LE, Pelican Instruments) [17]. Crude fat was extracted using petroleum ether in an automated Soxhlet extraction system (Socplus, Pelican Instruments) [18]. Crude fiber was estimated using an automated fiber analyzer (Fibraplus, Pelican Instruments) through sequential acid (0.255 N H_2SO_4) and alkali (0.313 N NaOH) digestion [19].
- **pH and Carbohydrates:** pH was measured using a digital pH meter (Biogen Scientific) calibrated with pH 4.0 and 7.0 buffer solutions [16]. Total carbohydrate was calculated by difference [20]:

$$\text{Carbohydrate (\%)} = 100 - [\text{Moisture (\%)} + \text{Protein (\%)} + \text{Fat (\%)} + \text{Ash (\%)} + \text{Fiber (\%)}]$$

2.4 Statistical Analysis

All experiments were conducted in triplicate using a Completely Randomized Design (CRD). Data were analyzed using MS Excel and SPSS software (Version 20.0). Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were used to test for significant differences among treatment means and storage periods at $p \leq 0.05$ and $p \leq 0.01$.

3. Results and Discussion

3.1 Moisture Content

The moisture content of fresh cookies (Day 0) ranged from 2.45% (T_0) to 2.96% (T_3) (Table 1). Higher incorporation levels of fruit pomace flour significantly increased the initial moisture levels ($p \leq 0.01$), driven by the high water-

binding capacity of fruit dietary fibers [21]. Over the 120-day ambient storage period, moisture content increased steadily across all treatments, reaching 3.23% in T_0 and 3.63% in T_3 . This upward trend is attributed to atmospheric moisture absorption through the HDPE packaging material [22].

3.2 Ash Content: Initial total ash content increased significantly with higher replacement levels, from 0.98% in T_0 to 1.81% in T_3 (Table 2). This increase highlights the mineral richness of apple and pineapple pomace compared to refined wheat flour [23]. During 120 days of ambient storage, ash content declined slightly but significantly across all samples (T_0 : 0.98% to 0.89%; T_3 : 1.81% to 1.72%), likely due to moisture gain and chemical interaction with minor mineral constituents over time.

Table 1: Effect of ambient storage on moisture content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value
T_0	3	2.45 ^{a,v} ± 0.055	2.64 ^{a,w} ± 0.023	2.83 ^{a,x} ± 0.023	3.02 ^{a,y} ± 0.012	3.23 ^{a,z} ± 0.017	2.83	103.82**
T_1	3	2.63 ^{b,v} ± 0.029	2.82 ^{b,w} ± 0.046	3.02 ^{b,x} ± 0.032	3.21 ^{b,y} ± 0.029	3.41 ^{b,z} ± 0.023	3.01	88.94**
T_2	3	2.79 ^{c,v} ± 0.035	2.98 ^{c,w} ± 0.023	3.18 ^{c,x} ± 0.017	3.49 ^{c,y} ± 0.040	3.56 ^{c,z} ± 0.012	3.22	173.85**
T_3	3	2.96 ^{d,v} ± 0.017	3.15 ^{d,w} ± 0.029	3.36 ^{d,x} ± 0.035	3.54 ^{d,y} ± 0.023	3.63 ^{d,y} ± 0.017	3.28	145.58**
Overall	12	2.71 ± 0.059	2.90 ± 0.059	3.10 ± 0.060	3.32 ± 0.065	3.49 ± 0.055	—	—
F-value	—	35.50**	47.23**	66.91**	76.30**	136.50**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

Table 2: Effect of ambient storage on total ash content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value (Storage)
T_0	3	0.98 ^{a,v} ± 0.005	0.96 ^{a,w} ± 0.003	0.95 ^{a,x} ± 0.003	0.93 ^{a,y} ± 0.009	0.89 ^{a,z} ± 0.005	0.94 ± 0.005	76.27**
T_1	3	1.25 ^{b,v} ± 0.003	1.23 ^{b,w} ± 0.009	1.20 ^{b,x} ± 0.006	1.18 ^{b,y} ± 0.006	1.17 ^{b,z} ± 0.003	1.20 ± 0.006	65.13**
T_2	3	1.52 ^{c,v} ± 0.008	1.49 ^{c,w} ± 0.006	1.47 ^{c,x} ± 0.005	1.45 ^{c,y} ± 0.006	1.42 ^{c,z} ± 0.006	1.47 ± 0.006	45.25**
T_3	3	1.81 ^{d,v} ± 0.006	1.79 ^{d,w} ± 0.003	1.77 ^{d,x} ± 0.006	1.75 ^{d,y} ± 0.005	1.72 ^{d,y} ± 0.008	1.77 ± 0.005	75.25**
Overall	12	1.39 ± 0.011	1.36 ± 0.005	1.34 ± 0.005	1.37 ± 0.005	1.30 ± 0.006	—	—
F-value	—	1365.26**	2541.27**	1354.24**	869.33**	865.36**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

3.3 Crude Protein Content

Freshly prepared cookies demonstrated a minor increase in crude protein with fruit pomace incorporation (T_0 : 7.33% vs. T_3 : 7.96%; Table 3). Over the 120-day storage period, protein content decreased across all formulations (T_0 : 7.33%

to 7.24%; T_3 : 7.96% to 7.76%). This reduction during ambient storage can be attributed to non-enzymatic browning (Maillard reaction) and slow protein degradation [24].

Table 3: Effect of ambient storage on crude protein content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value (Storage)
T_0	3	7.33 ^{a,w} ± 0.015	7.31 ^{a,w} ± 0.018	7.29 ^{a,w} ± 0.015	7.26 ^{a,xy} ± 0.018	7.24 ^{a,y} ± 0.012	7.29	5.95**
T_1	3	7.51 ^{b,w} ± 0.015	7.46 ^{b,w} ± 0.018	7.40 ^{b,x} ± 0.018	7.32 ^{a,y} ± 0.023	7.28 ^{a,y} ± 0.018	7.39	26.70**
T_2	3	7.81 ^{c,w} ± 0.017	7.75 ^{c,w} ± 0.023	7.68 ^{c,xy} ± 0.023	7.63 ^{b,yz} ± 0.026	7.59 ^{b,z} ± 0.023	7.69	15.83**
T_3	3	7.96 ^{d,w} ± 0.009	7.92 ^{d,w} ± 0.020	7.86 ^{d,xy} ± 0.020	7.81 ^{c,yz} ± 0.029	7.76 ^{c,z} ± 0.026	7.86	14.42**
Overall	12	7.65 ± 0.075	7.61 ± 0.073	7.56 ± 0.069	7.50 ± 0.069	7.47 ± 0.066	—	—
F-value	—	400.05**	195.15**	185.63**	115.31**	148.77**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

3.4 Fat Content

Fat content at Day 0 ranged from 21.74% in T_0 to 23.22% in T_3 (Table 4). During 120 days of ambient storage, fat levels showed a slight decrease across all treatments (T_0 : 21.74%

to 21.51%; T_3 : 23.22% to 23.06%). This reduction during storage is generally attributed to lipid oxidation and hydrolysis into free fatty acids triggered by absorbed moisture and trace oxygen within the package [25].

Table 4: Effect of ambient storage on fat content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value (Storage)
T_0	3	21.74 ^{a,w} ± 0.038	21.68 ^{a,w} ± 0.035	21.62 ^{a,xy} ± 0.026	21.58 ^{a,xy} ± 0.023	21.51 ^{a,z} ± 0.032	21.62	8.28**
T_1	3	22.65 ^{b,w} ± 0.032	22.60 ^{b,w} ± 0.029	22.55 ^{b,x} ± 0.029	22.42 ^{b,y} ± 0.026	22.35 ^{b,y} ± 0.032	22.51	17.66**
T_2	3	22.99 ^{c,w} ± 0.023	22.93 ^{c,w} ± 0.030	22.87 ^{c,xy} ± 0.032	22.81 ^{c,yz} ± 0.032	22.76 ^{c,z} ± 0.032	22.87	9.44**
T_3	3	23.22 ^{d,w} ± 0.019	23.18 ^{c,w} ± 0.019	23.12 ^{d,x} ± 0.026	23.09 ^{d,y} ± 0.015	23.06 ^{d,yz} ± 0.024	23.14	10.63**
Overall	12	22.65 ± 0.170	22.60 ± 0.172	22.55 ± 0.175	22.48 ± 0.172	22.42 ± 0.176	—	—
F-value	—	508.07**	529.71**	558.09**	697.89**	501.16**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

3.5 Dietary Fiber Content

Dietary fibre increased substantially with fruit pomace incorporation, from 1.12% in the control (T_0) to 3.83% in the T_3 formulation at Day 0 (Table 5). This marked enhancement reflects the elevated cellulose, hemicellulose,

and pectin contents inherent to apple and pineapple pomace matrices [26]. During 120 days of storage, dietary fibre decreased slightly (T_0 : 1.12% to 1.00%; T_3 : 3.83% to 3.68%), likely due to minor breakdown of soluble fiber constituents over extended storage [27].

Table 5: Effect of ambient storage on dietary fibre content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value (Storage)
T_0	3	1.12 ^{a,w} ± 0.020	1.11 ^{a,w} ± 0.015	1.06 ^{a,x} ± 0.012	1.02 ^{a,xy} ± 0.015	1.00 ^{a,y} ± 0.015	1.06	11.86**
T_1	3	3.21 ^{b,w} ± 0.023	3.18 ^{b,w} ± 0.024	3.16 ^{c,w} ± 0.026	3.12 ^{b,xy} ± 0.021	3.08 ^{b,y} ± 0.015	3.15	5.16**
T_2	3	3.49 ^{c,w} ± 0.021	3.44 ^{a,w} ± 0.026	3.40 ^{b,xy} ± 0.021	3.36 ^{d,xy} ± 0.023	3.33 ^{c,y} ± 0.026	3.40	6.91**
T_3	3	3.83 ^{d,w} ± 0.023	3.79 ^{c,w} ± 0.026	3.77 ^{d,w} ± 0.026	3.72 ^{c,xy} ± 0.026	3.68 ^{d,y} ± 0.026	3.76	5.10**
Overall	12	2.91 ± 0.318	2.88 ± 0.316	2.84 ± 0.318	2.80 ± 0.318	2.77 ± 0.315	—	—
F-value	—	3106.75**	2693.17**	3016.32**	3165.94**	13278.01**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

3.6 pH Values

The pH of fresh cookies dropped significantly with fruit pomace supplementation (T_0 : 7.03 vs. T_3 : 6.00; Table 6), driven by natural organic acids (malic and citric acids) present in apple and pineapple pomace [28]. Over 120 days of

ambient storage, pH values dropped steadily across all samples (T_0 : 7.03 to 6.45; T_3 : 6.00 to 5.48). This progressive acidification is primarily associated with the accumulation of free fatty acids from lipid hydrolysis and moisture pickup [29].

Table 6: Effect of ambient storage on pH of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value
T_0	3	7.03 ^a ± 0.020	6.92 ^a ± 0.015	6.78 ^a ± 0.012	6.67 ^a ± 0.015	6.45 ^a ± 0.015	6.77	241.68**
T_1	3	6.62 ^b ± 0.023	6.52 ^b ± 0.024	6.39 ^b ± 0.026	6.23 ^b ± 0.021	6.10 ^b ± 0.015	6.37	624.84**
T_2	3	6.33 ^c ± 0.021	6.19 ^c ± 0.026	6.02 ^c ± 0.021	5.91 ^c ± 0.023	5.77 ^c ± 0.026	6.04	631.40**
T_3	3	6.00 ^d ± 0.023	5.88 ^d ± 0.026	5.75 ^d ± 0.026	5.63 ^d ± 0.026	5.48 ^d ± 0.026	5.74	662.55**
Overall	12	6.50 ± 0.318	6.38 ± 0.316	6.24 ± 0.318	6.11 ± 0.318	5.95 ± 0.315	—	—
F-value	—	2383.68**	4489.00**	2885.16**	1448.37**	912.89**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

3.7 Total Carbohydrate Content

Total carbohydrate content at Day 0 ranged from 67.85% in T_0 to 74.25% in T_3 (Table 7). Among the composite formulations, carbohydrate content decreased as the proportion of fruit pomace increased (T_1 : 76.11% down to T_3 : 74.25%), corresponding to the inverse increase in ash, fiber, and protein fractions. Over the 120-day ambient

storage period, carbohydrate levels showed a slight downward trend across all treatments (T_0 : 67.85% to 67.21%; T_3 : 74.25% to 73.54%), which directly reflects the percentage recalculation following moisture uptake during storage [30].

Table 7: Effect of ambient storage on carbohydrate content (%) of composite cookies

Sample	N	Day 0	Day 30	Day 60	Day 90	Day 120	Treatment Mean	F-value (Storage)
T_0	3	67.85 ^{a,w} ± 0.040	67.68 ^{a,x} ± 0.043	67.56 ^{a,x} ± 0.024	67.37 ^{a,y} ± 0.046	67.21 ^{a,z} ± 0.043	67.53	39.00**
T_1	3	76.11 ^{b,w} ± 0.055	75.98 ^{b,w} ± 0.025	75.71 ^{b,x} ± 0.052	75.55 ^{b,y} ± 0.058	75.42 ^{b,y} ± 0.034	75.75	38.23**
T_2	3	75.84 ^{c,w} ± 0.052	75.69 ^{c,w} ± 0.058	75.53 ^{c,x} ± 0.033	75.36 ^{c,y} ± 0.044	75.21 ^{c,z} ± 0.043	75.52	29.46**
T_3	3	74.25 ^{d,v} ± 0.042	74.06 ^{d,w} ± 0.029	73.88 ^{d,x} ± 0.049	73.71 ^{d,y} ± 0.055	73.54 ^{d,z} ± 0.049	73.88	53.58**
Overall	12	73.51 ± 1.009	73.35 ± 1.012	73.17 ± 1.024	72.99 ± 1.027	72.84 ± 1.029	—	—
F-value	—	6560.01**	8914.57**	9056.82**	5958.03**	8571.52**	—	—

Values are Mean ± SEM. Means with different superscripts in a column (a-d) and row (v-z) differ significantly ($p \leq 0.05$).

4. Conclusion

This study demonstrates the viability of utilizing apple pomace flour (APF) and pineapple pomace flour (PPF) as functional ingredients to partially replace refined wheat flour in composite cookies. Incorporating equal blends of APF and PPF up to 30-40% significantly enhances the dietary fiber (up to 3.83%), ash (up to 1.81%), and protein content (up to 7.96%) of the product compared to 100% wheat flour control cookies. During 120 days of ambient storage in HDPE polythene packaging, moisture content increased from 2.45-2.96% to 3.23-3.63%, accompanied by minor decreases in ash, protein, fat, crude fiber, pH, and carbohydrate levels ($p \leq 0.01$). Despite these storage-induced changes, all composite cookies maintained acceptable quality attributes over the entire 120-day evaluation period. Overall, substituting 30% to 40% wheat flour with fruit pomace flour offers a commercially feasible strategy for producing fiber-rich, nutrient-dense cookies while advancing sustainable fruit-waste valorization in the food industry.

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