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# Studies on physicochemical and sensory characteristics of nutrient-rich biscuits prepared from blends of mango peel powder and *Amaranthus* seed flour

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## Abstract
This study examines biscuits made with blends of mango peel powder (MPP) and *Amaranthus* seed flour (ASF). The chemical compositions of mango peel powder and *Amaranthus* seed flour were analyzed to understand their nutritional profiles and potential as functional ingredients. Six treatments were formulated, varying in the proportions of wheat flour, mango peel powder, and *Amaranthus* seed flour. Six treatments were $T_1$: [Wheat flour (80%) + *Amaranthus* seed flour (20%)] $T_2$: [Wheat flour (80%) + Mango peel powder (20%), $T_3$: [Wheat flour (80%) + *Amaranthus* seed flour (10%) + Mango peel powder (10%)], $T_4$: [Wheat flour (70%) + *Amaranthus* seed flour (30%)], $T_5$: [Wheat flour (70%) + Mango peel powder (30%) and $T_6$: [Wheat flour (70%) + *Amaranthus* seed flour (15%) + Mango peel powder (15%)]. These formulations were analyzed for their sensory attributes, including color, texture, taste, mouthfeel, and overall acceptability. Physicochemical properties, including total phenolic and flavonoid content, pH, and antioxidant activity, were evaluated. The findings suggest that treatment $T_6$ demonstrated the most favourable sensory qualities and enhanced antioxidant properties, including DPPH (80.20±0.35), flavonoid content (13.45±0.52), and phenolic content (394.40±0.39). These characteristics indicate that $T_6$ is the most promising treatment for further development.


**Keywords:** Biscuits, fortification, mango peel powder, *Amaranthus* seed flour

## 1. Introduction
Biscuits are a popular snack enjoyed by many due to their versatility in accommodating various dietary needs. Despite concerns about their nutritional value, efforts are underway in the bakery industry to enhance their health benefits. One approach is incorporating natural sources of vitamins, minerals, polyphenols, and fiber, such as dried fruit and vegetable powders. These additions improve the biscuits' nutritional profile by increasing fiber content, while reducing fat and sugar levels compared to other snack products (Arepally *et al.*, 2020; Salehi, 2019) [4, 31].

Today, there is a preference for food rich in natural antioxidants, dietary fiber, natural colors and flavors, minerals, and vitamins, without synthetic additives. Fruits and vegetables are valued for their balanced profile of soluble and insoluble dietary fiber. Processing these often yields peels as a significant by-product, rich in dietary fiber and other beneficial compounds. These by-products can be repurposed across industries as natural, cost-effective sources of antioxidants, pectin, enzymes, organic acids, essential oils, and more, through methods like extraction, purification, and fermentation (Kodagoda *et al.*, 2017) [22].

Mango peel and seeds are significant by-products generated during mango consumption and processing, typically discarded as waste. However, they are rich in nutrients like carbohydrates, proteins, amino acids, lipids, vitamins, minerals, and phytochemicals such as carotenoids and phenolic compounds. To add value and reduce waste, these by-products can be converted into powders using methods like infrared, hot-air drying, or freeze-drying. Mango peel powders are valuable additives in various food products, enhancing their fiber, phenolic content, carotenoids, antioxidant activity, and glycemic index (Choudhary *et al.*, 2023; Maldonado-Celis *et al.*, 2019; Serna *et al.*, 2016; Marcal and Pintado, 2021) [12, 25, 33, 27].

*Amaranthus* is a robust crop known for its drought and pest resistance. Both its leaves and seeds are nutritionally rich, with seeds being high in fiber and low in saturated fats, making them popular in health foods. The oil from amaranth seeds contains beneficial fatty acids and antioxidants like tocopherols. Amaranth is also notable for its high protein content and essential amino acids such as lysine and cysteine. It is suitable for individuals with celiac disease due to its non-allergenic properties in the intestinal mucosa. Analyzing bioactive compounds such as squalene, β-sitosterol, and α-tocopherol in amaranth seed oils can enhance its potential as a nutraceutical for human consumption (Joshi and Verma, 2020) [21].

## 2. Materials and Methods

Ripe and healthy mangoes were purchased in the month of May from a nearby market in Jalandhar, Punjab. Matured and disease-free *Amaranthus* seeds were bought from a local market in Jalandhar, Punjab.

### 2.1 Methods

Laboratory methods and procedures used were adopted from Tobaruela *et al.*, (2018) [39]. Total soluble solids, Moisture content, titratable acidity, pH, total phenolic content, carbohydrates, ash content, crude fat, tannins, flavonoid content, antioxidant activity were estimated in the flours and the biscuits

### 2.2 Preparation of MPP

Collection of peels from fresh ripe mangoes
↓
Clean and rinse
↓
Steam blanching for 5 minutes
↓
Peels dried in tray drier (60+2 °C for 8-10 hours)
↓
Grind into flour
↓
Sieve through a 425 micron mesh metallic sieve (BSS Std. No. 36)
↓
Packaging in aluminum laminated pouches and stored at room temperature

### 2.3 Preparation of ASF

Collection of amaranthus seeds
↓
Clean and rinse
↓
Roast at 175 °C for 8-10 minutes.
↓
Grind into flour
↓
Sieve through a 425 micron mesh metallic sieve (BSS Std. No. 36)
↓
Packaging in aluminum laminated pouches and stored at room temperature

### 2.4 Treatment details

The biscuits were prepared using the creaming method based on the investigation by Molina *et al.*, (2021) [28]. Table 1 outlines the different combinations of fortification with mango peel powder, *Amaranthus* seed flour, and wheat flour.

**Table 1:** Treatment details

| Treatments | Wheat flour (%) | Mango peel powder (%) | *Amaranthus* seed flour (%) |
|---|---|---|---|
| $T_1$ | 80 | 0 | 20 |
| $T_2$ | 80 | 20 | 0 |
| $T_3$ | 80 | 10 | 10 |
| $T_4$ | 70 | 0 | 30 |
| $T_5$ | 70 | 30 | 0 |
| $T_6$ | 70 | 15 | 15 |

### 2.5 Sensory analysis

A nine-point hedonic scale was employed to analyze the sensory evaluation of the developed biscuits, assessing parameters such as color, texture, taste, aroma, and overall acceptability. The evaluation was conducted by 10 semi-trained judges.

## 3. Results and Discussion

### 3.1 Physico-chemical characteristics of mango peel powder and *Amaranthus* seed flour

The chemical properties of mango peel powder were analyzed, revealing the following composition: moisture content 7.92%±0.49 (Serna *et al.*, 2016; Ajila *et al.*, 2010) [33, 1]; Total Soluble Solids (TSS) 9.44°B±0.14 (Marcal *et al.*, 2021) [27]; pH 4.30±0.20 (Lebaka *et al.*, 2021) [23]; titratable acidity 0.18%±0.03; carbohydrates 72.60%±0.70 (higher than Madalageri *et al.*, 2017) [24]; ash content 4.07%±0.47 (Sogi *et al.*, 2013; Jahurul *et al.*, 2015) [36, 20]; fat content 2.53%±0.15 (Umamahesh *et al.*, 2020) [40]; total phenol 156.81 mg/100 g±0.37; total flavonoid 13.67 mg/100 g±0.40 (slightly higher than Serna *et al.*, 2016) [33]; tannin content 0.48 mg/100 g±0.02 (Gupta *et al.*, 2022) [17]; protein content 2.87%±0.45; and fiber content 46.83%±0.31 (Ibrahim *et al.*, 2017; Marcal *et al.*, 2021) [18, 27]. These findings highlight mango peel powder's potential as a functional ingredient in food and dietary applications.

**Table 2:** Chemical characteristics of Mango peel powder and *Amaranthus* seed flour

| Parameters | Mango peel Powder | *Amaranthus* seed flour |
|---|---|---|
| (Mean±SD) | | |
| Moisture (%) | 7.92±0.46 | 10.08±0.41 |
| TSS (°B) | 9.44±0.14 | 12.51±0.17 |
| pH | 4.30±0.20 | 4.96±0.68 |
| Titratable acidity (%) | 0.18±0.03 | 0.91±0.10 |
| Carbohydrates (%) | 72.60±0.70 | 61.51±0.75 |
| Ash (%) | 4.07±0.47 | 3.10±0.26 |
| Fat (%) | 2.53±0.15 | 6.57±0.67 |
| Total phenol (mg /100 g) | 156.81±0.37 | 89.24±0.80 |
| Total flavonoid (mg /100 g) | 13.67±0.40 | 8.20±0.39 |
| Tanin (mg/100 g) | 0.48±0.02 | 0.74±0.05 |
| Protein (%) | 2.87±0.45 | 15.40±0.71 |
| Fibre (%) | 46.83±0.31 | 4.43±0.42 |

The chemical composition of *Amaranthus* seed flour was analyzed, revealing the following nutritional profile: moisture content 10.08%±0.41 (Singh *et al.*, 2020; Escudero *et al.*, 2004) [35, 16]; Total Soluble Solids (TSS) 12.51°B±0.17 (Beniwal *et al.*, 2019) [9]; pH 4.96±0.68 (higher than Srivastava *et al.*, 2011); titratable acidity 0.91%±0.10 (Escudero *et al.*, 2011) [15]; carbohydrates 61.51%±0.75 (lower than Tanimola *et al.*, 2016; Malik *et al.*, 2023) [38, 26]; ash content 3.10%±0.26 (Akin *et al.*, 2017) [3]; fat content 6.57%±0.67 (De Bock *et al.*, 2021) [13]; total phenol 89.24

mg/100 g±0.80; total flavonoid 8.20 mg/100 g±0.39 (Isaac *et al.*, 2019; Sandoval *et al.*, 2020) [19, 32]; tannin content 0.74 mg/100 g±0.05 (Perales *et al.*, 2014) [29]; protein content 15.40%±0.71; and fiber content 4.43%±0.42 (Esan *et al.*, 2018; De Bock *et al.*, 2021) [14, 13]. These findings highlight *Amaranthus* seed flour's potential as a nutrient-rich ingredient in various food and dietary applications.

**Table 3:** Chemical characteristics of MPP and ASF fortified biscuits

| * | Moisture (%) | Fat (%) | Protein (%) | Carbohydrate (%) |
|---|---|---|---|---|
| Mean±SD | | | | |
| $T_1$ | 6.22±0.16$^{bc}$ | 20.35±0.56$^{c}$ | 13.44±0.35$^{c}$ | 60.01±0.86$^{e}$ |
| $T_2$ | 5.74±0.31$^{c}$ | 21.36±0.31$^{b}$ | 6.58±0.37$^{f}$ | 73.91±0.53$^{b}$ |
| $T_3$ | 6.89±0.39$^{a}$ | 19.41±0.44$^{d}$ | 12.54±0.39$^{d}$ | 75.79±0.27$^{a}$ |
| $T_4$ | 6.67±0.38$^{ab}$ | 21.50±0.64$^{b}$ | 16.40±0.34$^{a}$ | 57.92±0.68$^{f}$ |
| $T_5$ | 6.43±0.47$^{bc}$ | 22.46±0.40$^{a}$ | 7.32±0.38$^{e}$ | 72.16±0.78$^{d}$ |
| $T_6$ | 7.06±0.37$^{a}$ | 20.21±0.55$^{c}$ | 14.74±0.32$^{b}$ | 73.12±0.67$^{c}$ |

[$T_1$= 80% WF + 20% ASF, $T_2$= 80% WF + 20% MPP, $T_3$= 80% WF + 10% MPP + 10% ASF, $T_4$= 70% WF + 30% ASF, $T_5$= 70% WF + 30% MPP, $T_6$= 70% WF + 15% MPP + 15% ASF]
* - treatment combinations

**Table 4:** Antioxidant properties of MPP and ASF fortified biscuits

| * | pH | Flavonoid (mg/100 g) | Phenol (mg/100 g) | DPPH (%) |
|---|---|---|---|---|
| Mean±SD | | | | |
| $T_1$ | 6.79±0.02$^{a}$ | 7.45±0.17$^{d}$ | 67.62±0.57$^{f}$ | 77.76±0.54$^{c}$ |
| $T_2$ | 5.94±0.04$^{d}$ | 12.31±0.49$^{c}$ | 368.52±0.80$^{c}$ | 65.33±0.47$^{e}$ |
| $T_3$ | 6.49±0.08$^{b}$ | 11.28±0.35$^{c}$ | 254.26±0.41$^{d}$ | 78.91±0.55$^{b}$ |
| $T_4$ | 6.85±0.07$^{a}$ | 8.37±0.49$^{d}$ | 74.31±0.49$^{e}$ | 79.85±0.43$^{a}$ |
| $T_5$ | 6.08±0.05$^{c}$ | 15.18±0.68$^{a}$ | 402.15±0.80$^{a}$ | 66.39±0.36$^{d}$ |
| $T_6$ | 6.80±0.04$^{a}$ | 13.45±0.52$^{b}$ | 394.40±0.39$^{b}$ | 80.20±0.35$^{a}$ |

[$T_1$= 80% WF + 20% ASF, $T_2$= 80% WF + 20% MPP, $T_3$= 80% WF + 10% MPP + 10% ASF, $T_4$= 70% WF + 30% ASF, $T_5$= 70% WF + 30% MPP, $T_6$= 70% WF + 15% MPP + 15% ASF]
* - treatment combinations

### 3.2 Effect of different types of flour on biscuit's chemical properties

In Table 3, $T_4$ has the highest protein content at 16.40%±0.34, followed closely by $T_6$ at 14.74%±0.32. $T_2$ and $T_5$ have the lowest protein contents at 6.58%±0.37 and 7.32%±0.38, respectively. $T_1$ and $T_3$ show mid-range protein contents of 13.44%±0.35 and 12.54%±0.39, respectively. These findings align with studies by Ayo *et al.*, (2023) [7] and Puscas *et al.*, (2023) [30], indicating that biscuits made with *Amaranthus* seed flour tend to have higher protein content.

In Table 3, $T_5$ has the highest fat content at 22.46%±0.40, followed closely by $T_4$ at 21.50%±0.64 and $T_2$ at 21.36%±0.31. $T_3$ has the lowest fat content among the samples at 19.41%±0.44. $T_1$ and $T_6$ show moderate fat contents of 20.35%±0.56 and 20.21%±0.55, respectively. These results contrast with Chauhan *et al.*, (2015) [10], who reported lower fat contents in biscuits made with *Amaranthus* seed flour, and are comparable to findings by Ashoush *et al.*, (2011) [5] for biscuits made with wheat flour, oat flour, and mango peel powder.

In Table 3, $T_3$ has the highest carbohydrate content at 75.79%±0.27, followed closely by $T_6$ at 73.12%±0.67. $T_4$ has the lowest carbohydrate content among the samples at 57.92%±0.68. $T_1$, $T_2$, and $T_5$ show mid-range carbohydrate contents of 60.01%±0.86, 73.91%±0.53, and 72.16%±0.78, respectively. These findings align with Bandyopadhyay *et al.*, (2014) [8], who reported a 71.2% carbohydrate content in cookies with 20% mango peel powder, and Sindhuja *et al.*, (2005) [34], who reported a 59.3% carbohydrate content in biscuits made with 20% *Amaranthus* seed flour.

In Table 3, moisture content across treatments ($T_1$-$T_6$) ranges from 5.74% to 7.06%. $T_2$ has the lowest at 5.74%±0.31, and $T_6$ has the highest at 7.06%±0.37. $T_1$, $T_3$, $T_4$, and $T_5$ show intermediate levels with subtle differences. These variations could stem from ingredient differences, baking processes, or production environment. *Amaranthus* seed flour generally contains more moisture than mango peel powder (Singh *et al.*, 2020; Serna *et al.*, 2016) [35, 33], explaining higher moisture content in $T_1$ compared to $T_2$, and similarly in $T_4$ compared to $T_5$.

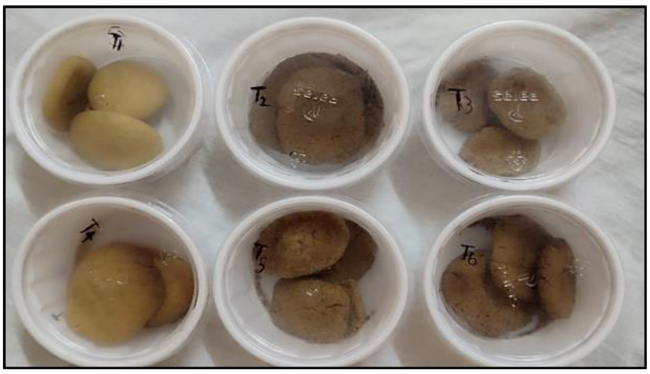
### 3.3 Effect of different types of flour on biscuit's antioxidant properties

Table 4 shows the phenolic content of biscuits made from different flours. $T_5$ has the highest phenol content at 402.15 mg/100 g±0.80, followed by $T_6$ at 394.40 mg/100 g±0.39. $T_1$ has the lowest at 67.62 mg/100 g±0.57. $T_2$, $T_3$, and $T_4$ have mid-range phenol contents of 368.52 mg/100 g±0.80, 254.26 mg/100 g±0.41, and 74.31 mg/100 g±0.49, respectively. The high phenolic content in $T_5$ and $T_3$ is due to the use of mango peel powder, which is richer in phenols than amaranth seed flour (Ashoush *et al.*, 2011; Chauhan *et al.*, 2016) [5, 11].

Table 4 indicates the flavonoid content of biscuits from different flours. $T_5$ shows the highest flavonoid content at 15.18 mg/100 g±0.68, followed closely by $T_6$ at 13.45 mg/100 g±0.52. $T_1$ has the lowest at 7.45 mg/100 g±0.17. $T_2$, $T_3$, and $T_4$ have mid-range flavonoid contents of 12.31 mg/100 g±0.49, 11.28 mg/100 g±0.35, and 8.37 mg/100 g±0.49, respectively. The higher flavonoid content in $T_5$ and $T_3$ is attributed to the use of mango peel powder, as suggested by Aslam *et al.*, (2014) [6] and Chauhan *et al.*, (2015) [10].

In Table 4, $T_4$ has the highest pH value at 6.85±0.07, indicating an alkaline environment. $T_6$ follows closely with a pH of 6.80±0.04. $T_2$ shows the lowest pH at 5.94±0.04, indicating acidity. $T_1$, $T_3$, and $T_5$ have mid-range pH values of 6.79±0.02, 6.49±0.08, and 6.08±0.05, respectively.

In Table 4, $T_5$ shows the highest DPPH scavenging activity at 80.20%±0.35, indicating strong antioxidant capability. $T_4$ follows closely with 79.85%±0.43. $T_2$ exhibits the lowest activity at 65.33%±0.47. $T_1$, $T_3$, and $T_6$ have mid-range scavenging activities of 77.76%±0.54, 78.91%±0.55, and 66.39%±0.36, respectively. These results are consistent with findings by Ajila *et al.*, (2008) [2], Escudero *et al.*, (2011) [15], and Esan *et al.*, (2018) [14].



Biscuits with Different Varied Treatments

### 3.4 Sensory Evaluation
The provided dataset presents the results of a comprehensive sensory analysis conducted on biscuits of varying compositions, designated as $T_1$ to $T_6$. This evaluation encompassed key sensory attributes including colour and appearance, texture, taste and aroma, mouthfeel, and overall acceptability. Across all assessed attributes, the biscuits garnered consistently favorable evaluations. Mean scores ranged from 6.95 to 8.34 on a scale extending from 1 to 9, indicating a generally high level of sensory satisfaction among panelists. Specifically, evaluations of colour and appearance revealed ratings spanning from 7.10 to 8.60, suggesting a visually appealing presentation across the tested samples. Texture assessments yielded scores falling between 7.00 and 8.40, indicative of a desirable consistency and mouthfeel profile. Ratings for taste and aroma ranged from 6.90 to 8.35, underscoring the enjoyable and flavourful characteristics of the biscuits across the spectrum of compositions. Additionally, perceived mouthfeel received generally positive feedback, with average scores ranging from 6.60 to 8.10, highlighting a well-balanced amalgamation of crispness and chewiness. The positive outcomes of this sensory evaluation indicate that the biscuit formulations have not only met but exceeded expectations. This success highlights the potential for further exploration and optimization of biscuit compositions. By continuing to refine formulations based on sensory feedback, manufacturers can enhance consumer satisfaction and acceptance, ultimately strengthening brand loyalty and market competitiveness.

**Table 5:** Evaluation of fortified biscuits on the sensory characteristics / Sensory Evaluation

| Treatments | Colour / Appearance | Texture / Hardness | Taste | Mouth feel | Overall acceptability |
|---|---|---|---|---|---|
| $T_1$ | 7.70±1.16$^b$ | 7.00±1.05$^d$ | 6.90±0.74$^d$ | 6.60±1.35$^c$ | 7.05±0.75$^c$ |
| $T_2$ | 7.60±0.84$^c$ | 7.20±0.63$^c$ | 7.20±0.92$^b$ | 6.90±0.74$^b$ | 7.23±0.46$^b$ |
| $T_3$ | 8.60±0.70$^a$ | 8.15±0.82$^b$ | 8.35±0.67$^a$ | 7.65±0.88$^a$ | 8.19±0.56$^a$ |
| $T_4$ | 7.75±0.98$^b$ | 7.40±1.07$^c$ | 7.05±1.21$^c$ | 6.90±1.29$^b$ | 7.28±0.83$^b$ |
| $T_5$ | 7.10±0.88$^d$ | 7.00±1.05$^d$ | 7.00±1.05$^c$ | 6.70±1.06$^c$ | 6.95±0.56$^d$ |
| $T_6$ | 8.50±0.71$^a$ | 8.40±0.70$^a$ | 8.35±0.82$^a$ | 8.10±0.91$^a$ | 8.34±0.56$^a$ |

## 4. Conclusion
This study highlights mango peel powder and *Amaranthus* seed flour as beneficial ingredients in biscuits. Biscuits with higher mango peel powder content show increased phenolic and flavonoid content and stronger antioxidant properties. $T_6$ stands out with balanced nutritional profiles, high protein, significant fat, moderate moisture, and strong antioxidant activities. $T_1$ exhibits lower phenolic content and moderate nutritional values. $T_2$, with low protein and moisture but high carbohydrates, offers substantial energy. $T_3$ is characterized by high carbohydrates and moisture, moderate protein and fat, and moderate antioxidants. $T_6$ also received the highest sensory scores, indicating superior overall acceptability. Further research could optimize biscuit formulations to enhance nutritional benefits and sensory appeal, meeting consumer demand for healthier and tastier snacks. Our study recommends $T_6$, comprising 70% wheat flour, 15% *Amaranthus* seed flour, and 15% mango peel powder, due to its nutrient richness and excellent sensory qualities.

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