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Evaluation of nutritional, techno-functional and antioxidant properties of fruit pomace powder

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Abstract
Fruit processing generates substantial quantities of pomace, which is often discarded despite its potential nutritional and functional value. The present study aimed to characterize and compare orange, pineapple, and sweet lime pomace powders based on their physicochemical, proximate, mineral, functional, and bioactive properties. The pomaces were dried, milled, and evaluated for moisture, ash, fat, protein, carbohydrate, crude fibre, mineral composition, water and oil absorption capacities, swelling capacity, solubility, total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity. Moisture content ranged from 6.3–7.0%, indicating effective drying and good storage stability, while ash content varied from 3.9–4.5%. Sweet lime pomace showed the highest fat content (2.6–4.3%), whereas protein content varied comparatively little (5.8–6.3%). Carbohydrates were the predominant proximate component, ranging from 72.1–73.8%, with pineapple pomace exhibiting the highest value, while crude fibre ranged from 7.0–7.3%. Citrus pomaces demonstrated higher water absorption capacity than pineapple pomace, reflecting their greater hydrophilic and pectin-rich components. Orange pomace exhibited the highest TPC (22.64 ± 0.74 mg GAE/g) and TFC (15.82 ± 0.51 mg QE/g), indicating greater antioxidant potential, while pineapple showed comparatively lower bioactive values and sweet lime displayed intermediate characteristics. Overall, the findings demonstrate that orange, pineapple, and sweet lime pomace powders possess valuable nutritional, functional, and bioactive properties and may serve as sustainable ingredients for the development of fibre-enriched, nutritionally improved, and functional food products.

Keywords: Fruit pomace, orange pomace, pineapple pomace, sweet lime pomace, functional properties, bioactive compounds, antioxidant activity, food waste valorisation

Introduction

The rapid growth of fruit-processing industries has resulted in the generation of substantial quantities of processing by-products, particularly peels, pulp residues, seeds, membranes, and fibrous pomace (Singh *et al*., 2026) [35]. These materials are often discarded or subjected to low-value applications despite containing considerable amounts of nutrients and biologically active compounds (Domínguez *et al*., 2026) [12]. The valorization of fruit-processing residues has therefore emerged as an important approach for reducing food waste, recovering valuable nutrients, and promoting sustainable and circular food systems. Fruit pomaces are increasingly recognized as promising sources of dietary fibre, minerals, phenolic compounds, flavonoids, carotenoids, and other bioactive constituents, which may provide both nutritional and technological benefits when incorporated into food products (Capanoglu *et al*., 2022; Raczkowska & Serek, 2024; Gomes *et al*., 2025) [8, 18, 32].

Among different fruit-processing residues, citrus and pineapple pomaces are of particular interest because of their distinctive nutritional and phytochemical profiles. Orange and sweet lime pomaces contain appreciable amounts of dietary fibre, pectin, minerals, flavonoids, phenolic compounds, and other phytochemicals, whereas pineapple pomace provides valuable dietary fibre, carbohydrates, minerals, and antioxidant constituents. The composition of these residues can vary according to fruit species, cultivar, maturity, geographical conditions, processing techniques, and subsequent drying and storage conditions (Arcia *et al*., 2024; Gomes *et al*., 2025; Romero-Martínez *et al*., 2025) [3, 18, 33]. Such variation can substantially influence their suitability for different food applications.

Conversion of fresh pomace into powder form provides an effective strategy for improving its stability, handling, transportation, and incorporation into food matrices. Drying and milling reduce the perishability of fruit residues and facilitate their utilization in bakery products, beverages, snacks, fibre-enriched formulations, and other value-added foods. However, the technological performance of pomace powders depends on their physical and functional properties, including particle size, bulk density, porosity, flowability, water absorption capacity, oil absorption capacity, swelling capacity, and solubility. These characteristics influence powder handling, mixing, hydration, storage, and interactions with other food components (Raczkowska & Serek, 2024; Gomes et al., 2025) [18, 32].

In addition to their nutritional and technological value, fruit pomaces represent important sources of natural antioxidant compounds. Phenolic compounds and flavonoids contribute substantially to the antioxidant potential of fruit-processing residues, while citrus pomaces are particularly associated with bioactive compounds such as hesperidin, narirutin, eriocitrin, naringin, and phenolic acids (Arcia *et al*., 2024) [3]. Evaluation of total phenolic content, total flavonoid content, and radical-scavenging activity can therefore provide useful information regarding the functional and bioactive potential of pomace powders.

Although individual fruit by-products have been widely investigated, comparative assessment of orange, pineapple, and sweet lime pomace powders under similar processing and analytical conditions remains comparatively limited. A systematic comparison of their physicochemical, proximate, mineral, functional, and antioxidant characteristics is important for identifying their relative nutritional and technological advantages and for selecting appropriate materials for specific food applications. Therefore, the present study was undertaken to explore and comparatively evaluate the nutritional, mineral, functional, physicochemical, and antioxidant potential of orange, pineapple, and sweet lime pomace powders as sustainable value-added food ingredients. The findings may support the effective valorization of fruit-processing residues while contributing to the development of nutritionally enhanced and functionally improved food products.

Materials and Methodology

Materials

Fresh pomace residues of orange (*Citrus sinensis*), pineapple (*Ananas Comosus*), and sweet lime (*Citrus limetta*) were obtained immediately after juice extraction from local fruit processing units in Beed. All chemicals and reagents utilized for analytical procedures were of analytical grade.

Preparation of fruit pomace powder

Following juice extraction, the collected pomaces were immediately transferred into polyethylene bags and stored under refrigerated conditions (4 ± 1ºC) to minimize microbial growth and enzymatic deterioration. The pomaces were thoroughly washed with distilled water to remove residual sugars and adhering pulp particles, manually deseeded, and allowed to drain. Subsequently, the cleaned pomaces were dried in a hot air oven at 60º until achieving a constant weight. The dried pomace samples were pulverized using grinder, passed through a 250 µm mesh sieve, and stored in airtight LDPE polyethylene pouches at 4ºC until further analytical evaluation (Sobti *et al*., 2025; Afrin *et al*., 2022) [2, 37].

Physicochemical Analysis

Colour evaluation

The colour characteristics of the samples were evaluated with Hunter Lab Miniscan XE Plus. Before measurement, the instrument was calibrated using standard white and black calibration tiles according to the manufacturer's instructions. The sample was placed in a clean sample cup to obtain a smooth and uniform surface. The colour parameters L* (Lightness), a* (redness) and b* (yellowness) were recorded, and ΔE, which measures the colour difference, was calculated. Chroma (*C**) was calculated using Formula (Devi *et al*., 2016) [11].

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

Bulk density and Tapped density

Bulk and tapped densities were determined with slight modifications. Briefly, 4 g of pomace powder was placed in a 25 mL graduated cylinder to measure the initial volume (bulk density). The cylinder was then tapped until a constant volume was achieved to determine the tapped density. Both densities were calculated as the ratio of sample mass to the corresponding volume (g/mL) (Traina *et al*., 2013) [38].

Porosity

The porosity (%) was calculated from the bulk density (ρ_β) and tapped density (ρ_t) using the following equation (Demircan *et al*., 2023) [10].

$$Porosity\ (\%) = (1 - \frac{\rho p}{\rho b}) \times 100$$

Carr's Index & Hausner Ratio

Carr's Index (CI) was calculated from the bulk and tapped density values according to the method described by Aryaee *et al*. (2023) [4] using the following equation.

$$Carr's Index = \frac{Tapped\ Density - Bulk\ density}{Tapped\ Density} \times 100$$

$$Hausner\ Ratio = \frac{Tapped\ Density}{Bulk\ Density}$$

Proximate Analysis

The nutritional composition of the fruit-pomace powders was evaluated by determining moisture, ash, protein, fat, fibre, carbohydrate, and energy content following standard AOAC (2019) official analytical procedures, with minor modifications where necessary. Moisture and ash contents were measured using conventional gravimetric techniques, whereas protein and fat contents were estimated using standard Kjeldahl and solvent-extraction methods, respectively. Crude fibre was determined using the recommended fibre-analysis procedure. The carbohydrate content was obtained by difference, and the calorific value was calculated using the Atwater factors of 4 kcal/g for protein and carbohydrate and 9 kcal/g for fat. Each analysis was conducted in three independent replicates to improve analytical reliability. The results were presented as mean ± SE and expressed on a dry-weight basis to allow meaningful comparison among the different fruit-pomace samples.

Sensory Analysis

The sensory characteristics of the developed edible bowls were assessed using a 9-point hedonic rating scale. A panel comprising 20 semi-trained panellists evaluated the samples for key sensory attributes, including colour, appearance, taste, texture, and overall acceptability. Each attribute was scored from 1 to 9, where a score of 9 represented *"like extremely"* and a score of 1 represented *"dislike extremely."* The samples were coded and presented to the panellists under controlled evaluation conditions to minimize bias. Panellists were instructed to evaluate each sample independently and to rinse their mouths with water between samples to minimize carry-over effects. The mean sensory scores were calculated for each attribute and used to compare the acceptability of the different edible-bowl formulations.

Mineral Content Analysis

The mineral composition of the samples, particularly calcium (Ca), magnesium (Mg), potassium (K), and iron (Fe), was analysed following the procedures described in the AOAC Official Methods (2019). The samples were first subjected to appropriate acid digestion to release the mineral elements into solution. The resulting digests were subsequently analysed using an Atomic Absorption Spectrophotometer (AAS) under suitable instrumental conditions for each mineral. Calibration was performed using standard solutions of known concentrations, and appropriate blanks and quality-control procedures were included during analysis. The concentrations of the individual minerals were calculated from the respective calibration curves and expressed as mg/10 g dry weight (DW) of the sample. All determinations were carried out in replicate, and the results were reported as mean values with appropriate measures of variability.

Functional Properties analysis

The functional characteristics of the samples were evaluated by determining water absorption capacity (WAC), oil absorption capacity (OAC), water solubility, and swelling capacity using standardized centrifugation-based procedures with appropriate modifications, following the method described by Naseem *et al*. (2024) [30]. These parameters were assessed to determine the ability of the samples to interact with water and oil and to evaluate their potential technological performance in food formulations.

For WAC and OAC, a known quantity of sample was mixed separately with measured amounts of distilled water or edible oil, allowed to equilibrate, and then centrifuged to separate the unabsorbed liquid. The absorbed liquid was quantified from the difference between the initial and recovered amounts and expressed relative to the sample weight. Water solubility was determined from the proportion of sample solids dissolved in the aqueous phase after centrifugation and drying of the recovered supernatant. Swelling capacity was evaluated by measuring the increase in sample volume after hydration under controlled conditions. All measurements were conducted in replicate, and the results were expressed as mean ± SE to facilitate comparison among the different samples.

Antioxidant activity, Total Phenolic content and Total Flavonoid content

The antioxidant and bioactive properties of the samples were assessed by determining DPPH radical-scavenging activity, total phenolic content (TPC), and total flavonoid content (TFC) using established spectrophotometric procedures. The free-radical-scavenging potential was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, in which the reduction in absorbance resulting from the interaction between the sample extract and DPPH radicals was measured at 517 nm using a UV–Visible spectrophotometer. The percentage of radical-scavenging activity was calculated relative to the appropriate control (Brand-Williams *et al*., 1995) [6]. Total phenolic content was estimated using the Folin–Ciocalteu colorimetric method, with gallic acid used as the reference standard (Singleton *et al*., 1999) [36], whereas total flavonoid content was determined using the aluminium chloride ($AlCl_3$) colorimetric method, with quercetin used as the standard (Chang *et al*., 2002) [9]. The TPC and TFC values were calculated from their respective calibration curves and expressed as mg gallic acid equivalents (GAE)/g dry weight and mg quercetin equivalents (QE)/g dry weight, respectively.

Antioxidant activity was expressed as percentage DPPH radical inhibition. All analyses were performed in replicate, and the results were reported as mean ± SE.

Statistical Analysis

Statistical analysis of the experimental data was carried out using Minitab version 20, following the statistical approach described by Dubey *et al*. (2023). All measurements were performed in triplicate, and the results were presented as mean ± standard deviation (SD). Differences among the experimental groups were evaluated using one-way analysis of variance (ANOVA). When a statistically significant difference was detected, Tukey's Honestly Significant Difference (HSD) post-hoc test was applied for pairwise comparison of the treatment means. Statistical significance was evaluated at a 95% confidence level, and differences were considered statistically significant when $p < 0.05$. The statistical analysis was used to determine whether the observed differences among the samples for physicochemical, nutritional, functional, antioxidant, and sensory characteristics were statistically meaningful.

Results and Discussion

Drying of fruit pomace

Fresh orange, pineapple, and sweet lime pomace obtained after juice extraction were cleaned, de-seeded, and dried in a hot-air tray dryer at 60 ºC. The samples were uniformly spread on stainless steel trays and dried under controlled conditions until the moisture content reached ≤8%. The optimized drying process enhanced shelf stability and yielded pomace suitable for subsequent milling and formulation of edible bowl products.

Colour evaluation of fruit pomace powder

Colour is a crucial parameter that influences the sensory quality and overall consumer acceptance of food products, as it is greatly affected by consumer preference, perception and buying behaviour. Therefore, the evaluation of colour parameters is considered as an essential aspect of a food technology and product development.

The colour profile of orange, pineapple and sweet lime pomace powders was determined using the CIE Lab* colour space, where L* denotes lightness, a* represents the red-green axis, and b* indicates the yellow-blue axis.

Table 1: Colour evaluation of fruit pomace powders

Samples	L* (Lightness)	a* (Redness)	b* (Yellowness)	Croma (C*)	Hue (h°)
Orange pomace powder	63.7 ± 0.6	6.2 ± 0.4	38.6 ± 0.6	39.09 ± 1.04	80.9º ± 0.7
Pineapple pomace powder	69.9 ± 0.8	4.1 ± 0.3	34.5 ± 0.7	34.74 ± 0.92	83.2º ± 0.8
Sweet lime pomace powder	65.9 ± 0.7	9.1 ± 0.3	34.8 ± 0.7	35.97 ± 0.96	75.3º ± 0.7

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

Table 1 summarizes the colour attributes (L*, a*, b*) of fruit pomace powders, showing marked variation among samples attributable to differences in intrinsic pigment composition and processing-induced changes during drying. Pineapple pomace powder recorded the highest lightness (L*, 69.9 ± 0.8), indicating reduced browning and better colour retention under the applied drying conditions. Sweet lime pomace powder exhibited the highest redness (a*, 9.2 ± 0.4), while pineapple pomace showed the lowest a* value (4.1 ± 0.3), reflecting comparatively lower red hue development. Orange pomace powder recorded the highest yellowness (38.6 ± 0.6), which can be associated with higher carotenoid content. Overall, orange pomace was characterized by a deeper yellow hue, sweet lime by a slightly more reddish-yellow tone, and pineapple pomace by higher lightness with minimal pigment darkening. These differences highlight the role of fruit matrix and thermal processing in determining the final colour quality of pomace-based powders.

Similar trends have been reported in previous studies where dried orange pomace powders at different temperatures showed L*, a* and b* values ranging from 77.12 to 81.16, 3.78 to 7.69, and 25.06 to 36.51, respectively, indicating high yellowness and moderate redness after drying. Freeze-dried pineapple pomace powder was reported to possess L*, a* and b* values of 76.38, 3.26, and 30.36, respectively, confirming its light-yellow colour characteristics and low redness values, which are comparable with the present findings.

Physical properties of fruit pomace

Physical properties of fruit pomace powders play an important role in determining their suitability for food applications, which influence the processing behaviour, storage stability, handling properties, and consumer acceptability of the final product.

Table 2: Physical properties of fruit pomace

Samples	Bulk density (g/ cm^3)	Porosity (%)	Mean particle size (µm)	Tapped density	Carr's index	Hausner Ratio
Orange pomace powder	0.58 ± 0.01	58.64 ± 0.72	182.4 ± 4.2	0.69 ± 0.02	15.94 ± 0.44	1.19 ± 0.01
Pineapple pomace powder	0.49 ± 0.02	63.81 ± 0.65	196.7 ± 5.1	0.61 ± 0.01	19.67 ± 0.52	1.24 ± 0.02
Sweet lime pomace powder	0.56 ± 0.01	59.47 ± 0.81	176.9 ± 3.8	0.67 ± 0.02	16.42 ± 0.37	1.20 ± 0.01

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

Orange pomace powder exhibited the highest bulk density (0.58 ± 0.01 g/cm^3), followed by sweet lime (0.56 ± 0.01 g/cm^3), while pineapple pomace powder showed the lowest value (0.49 ± 0.02 g/cm^3), likely due to its fibrous structure and reduced particle packing. Pineapple pomace also recorded the highest porosity (63.81%), which may enhance water absorption and improve dough formation during edible bowl preparation. Particle size analysis showed that the sweet lime pomace had the finest particles (176.9 ± 3.8 µm), whereas pineapple pomace had the largest particles (196.7 ± 5.1 µm), reflecting differences in fibre characteristics and grinding efficiency.

Flowability parameters indicated that orange pomace powder has the lowest Carr's Index (15.94%) and Hausner ratio (1.19), that suggests better flowability and lower cohesiveness, whereas pineapple pomace powder exhibited the highest values (19.67% and 1.24), likely due to its higher porosity and larger particle size. Sweet lime pomace powder showed intermediate values. All powders had Carr's Index below 20% and Hausner ratio below 1.25, indicating acceptable flow properties suitable for uniform mixing, mould filling, and edible bowl preparation.

Proximate analysis of fruit pomace

Table 3: Proximate content of fruit pomace

Sample	Moisture (%Wb)	Ash (%Db)	Fat (%Db)	Protein (%Db)	Carbohydrate (%Db)	Crude Fibre (%Db)
Orange pomace powder	6.3 ± 0.2	4.5 ± 0.1	2.6 ± 0.3	6.3 ± 0.4	72.3 ± 0.6	7.2 ± 0.1
Pineapple pomace powder	7.0 ± 0.4	3.9 ± 0.2	3.9 ± 0.2	5.8 ± 0.12	73.8 ± 0.4	7.0 ± 0.1
Sweet lime pomace powder	6.5 ± 0.1	4.3 ± 0.1	4.3 ± 0.2	6.0 ± 0.4	72.1 ± 0.5	7.6 ± 0.3

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

Table 3 represents the proximate composition of orange, pineapple, and sweet lime pomace powders. Moisture content ranged from 6.3 – 7.0%, indicating effective drying and good storage stability. These values agree with those reported by Meena *et al*. (2022), and Munjaji *et al*. (2022) [27, 28]. Ash content varied between 3.9 – 4.5%, with orange pomace powder recording the highest value, reflecting its higher mineral content. Similar ash values have been reported by Camacho et al., Arcia *et al*. (2024) [3], Selani *et al*., and Meena *et al*. (2022) [27]. Sweet lime pomace exhibited the highest fat content (2.6-4.3%), whereas protein content varied only slightly (5.8-6.3%) among the samples, suggesting that fruit pomace powders can contribute to the nutritional quality of value-added food products. These findings are comparable with those of Selani *et al*., Samandeep Kaur et al. (2025), Nagarajaiah Prakash (2016) [21, 29], and the review by Raczkowska and Serek (2024) [32].

Carbohydrates were the major constituents (72.1-73.8%), with pineapple pomace containing the highest level, consistent with previous reports by Nagarajaiah Prakash (2016) [29], Mahato *et al*., and Ketnawa *et al*., (2022) [22]. Crude fibre for all the pomace powders ranged from 7.0 to 7.3%, confirming its fibre-rich nature. Similar observations have been reported by Abdel-Hamid *et al*. (2022), Manthei *et al*. (2024), Gumber *et al*. (2024) [1, 3, 19], supporting the use of fruit pomace powders as functional ingredients for fibre enrichment and the development of nutritionally enhanced food products.

Mineral content of fruit pomace

Table 4: Mineral content of fruit pomace

Sample	Potassium (K) (mg/100g)	Calcium (Ca) (mg/100g)	Magnesium (Mg) (mg/100g)	Iron (Fe) (mg/100g)
Orange pomace powder	842.6 ± 12.4	168.3 ± 4.1	74.5 ± 2.2	2.84 ± 0.09
Pineapple pomace powder	715.8 ± 10.7	121.6 ± 3.5	62.9 ± 1.8	1.96 ± 0.07
Sweet lime pomace powder	801.4 ± 11.3	154.7 ± 3.8	69.8 ± 2.0	2.61 ± 0.08

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

Table 4 shows that all fruit pomace powders contained appreciable amounts of essential macro- and micro-minerals. Orange pomace powder contained the highest levels of potassium (842.6 ± 12.4 mg/100g), calcium (168.3 ± 4.1 mg/100g), magnesium (74.5 ± 2.2 mg/100g), and iron (2.84 ± 0.09 mg/100g), followed by sweet lime and pineapple pomace powders. The higher mineral content in citrus pomaces is due to retention of mineral-rich tissues during juice extraction, with potassium being the predominant mineral in all samples.

The mineral profile observed in this study is consistent with previous reports by Mahato *et al*. (2022) [24], who reported high potassium and calcium content in citrus pomace and moderate mineral levels in pineapple pomace powder. Similar findings were highlighted in the review by Raczkowska and Serek, and Agata Blicharz-Kania *et al.* (2025), which identified fruit pomaces as valuable sources of potassium, calcium, magnesium, and iron. Harsh Kumar *et al*. emphasized the nutritional significance of fruit processing by-products as rich sources of minerals and dietary fibre.

Functional properties of fruit pomace

Table 5: Functional properties of fruit pomace

Samples	WAC (g/g)	OAC (g/g)	SC (ml/g)	Solubility (%)
Orange pomace powder	5.84 ± 0.13	2.0 ± 0.06	6.7 ± 0.15	18.4 ±0.48
Pineapple pomace powder	4.8 ± 0.17	2.1 ± 0.07	7.1 ± 0.19	15.9 ± 0.41
Sweet lime pomace powder	5.6 ± 0.12	1.9 ± 0.05	6.3 ± 0.14	17.9 ± 0.45

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

The functional characteristics of orange, pineapple, and sweet lime pomace powders are summarized in Table 5. Variations in water absorption capacity, oil absorption capacity, swelling capacity, and solubility were observed among the samples, which is assigned by the differences in fibre composition, particle structure, and the proportion of soluble and insoluble fibre fractions. Citrus pomaces demonstrated better water absorption capacity, with values of 5.48 ± 0.13 g/g for orange and 5.6 ± 0.12 g/g for sweet lime, compared with 4.8 ± 0.17 g/g for pineapple pomace. This behaviour may be linked to the higher pectin content and hydrophilic nature of citrus fibre components. (Mahato *et al*., 2022), Raczkowaska and Serek (2024) [24, 32].

The oil absorption capacity of the powders remained comparable (1.9-2.1 g/g), with pineapple pomace showing slightly improved oil retention, possibly due to its porous fibre network and surface characteristics. In contrast, swelling behaviour was more pronounced in pineapple pomace (7.1 ± 0.19 ml/g), indicating greater fibre expansion upon hydration. Solubility ranged between 15.9 and 18.4%, with improved dissolution properties observed in citrus pomaces, which may result from their higher soluble polysaccharides content. (Raczkowska and Serek (2024; Harsh Kumar *et al*. (2024) [32].

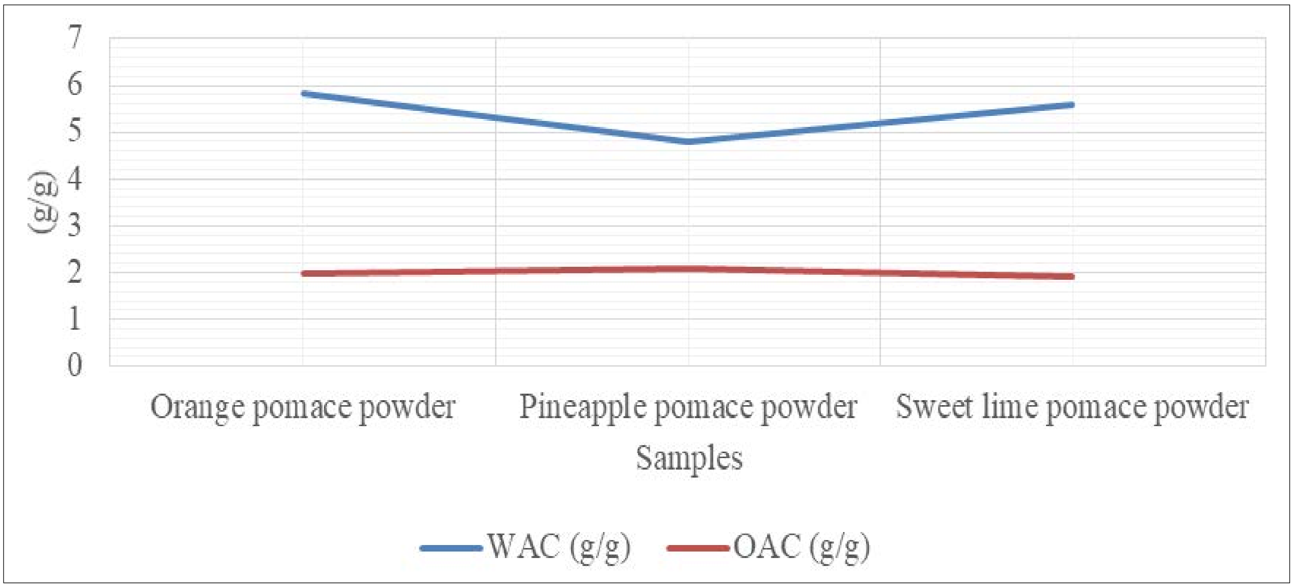

Fig 1: Water absorption capacity and Oil absorption capacity of fruit pomace powders

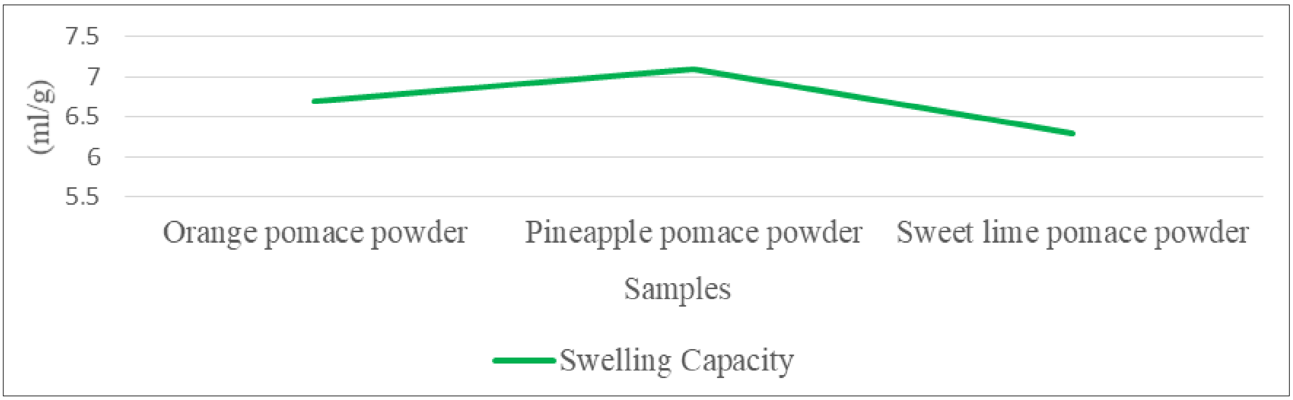

Fig 2: Swelling Capacity of fruit pomace powders

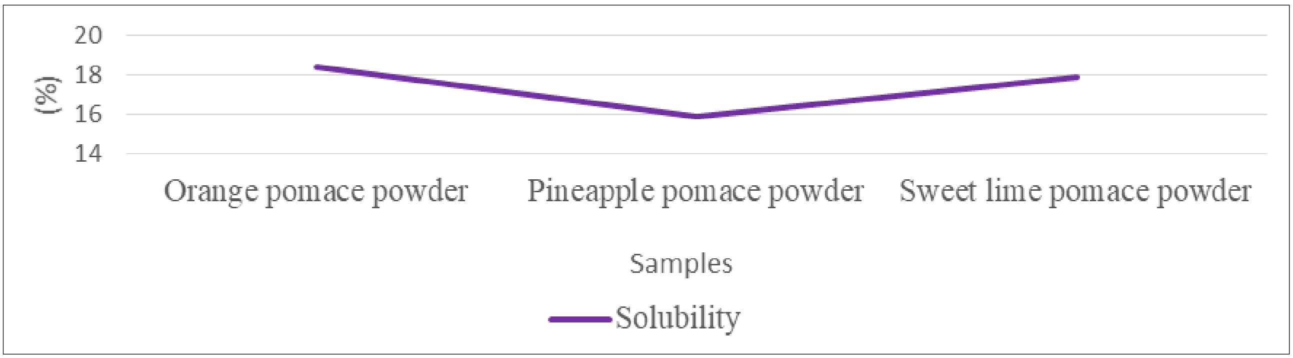

Fig 3: Solubility of fruit pomace powders

Antioxidant properties of fruit pomaces

Table 6: Antioxidant properties of fruit pomace

Samples	TPC (mg GAE/g)	TFC (mg QE/g)	Antioxidant content (%)
Orange pomace powder	22.64 ± 0.74	15.82 ± 0.51	58.25 ± 0.13
Pineapple pomace powder	18.37 ± 0.62	10.54 ± 0.38	57.69 ± 0.36
Sweet lime pomace powder	20.91 ± 0.68	12.96 ± 0.47	55.62 ± 0.20

*Each value is the mean ± standard deviation of three independent determinations (n = 3).

Table 6 summarizes the bioactive composition of fruit pomace powders, highlighting differences in total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity among the samples. Orange pomace powder contained the highest TPC (22.64 ± 0.74 mg GAE/g) and TFC (15.82 ± 0.51 mg QE/g), whereas pineapple pomace powder showed comparatively lower values. Sweet lime pomace resulted in intermediate levels of these bioactive compounds. The higher concentration of phenolic compounds in citrus pomaces may be related to the presence phenolic acids, flavanone glycosides, hesperidin, and narirutin retained in the fibrous portions after juice processing. Similar findings were reported by Arcia et al. (2024) [3].

Antioxidant activity of the pomace powders varied between 55.62-58.25%, with orange pomace powder demonstrating stronger antioxidant potential. This response corresponds with its greater phenolic and flavonoid concentration, while the considerable activity observed in pineapple pomace may be linked to the presence of other antioxidant components, including vitamin C and phenolic acids.

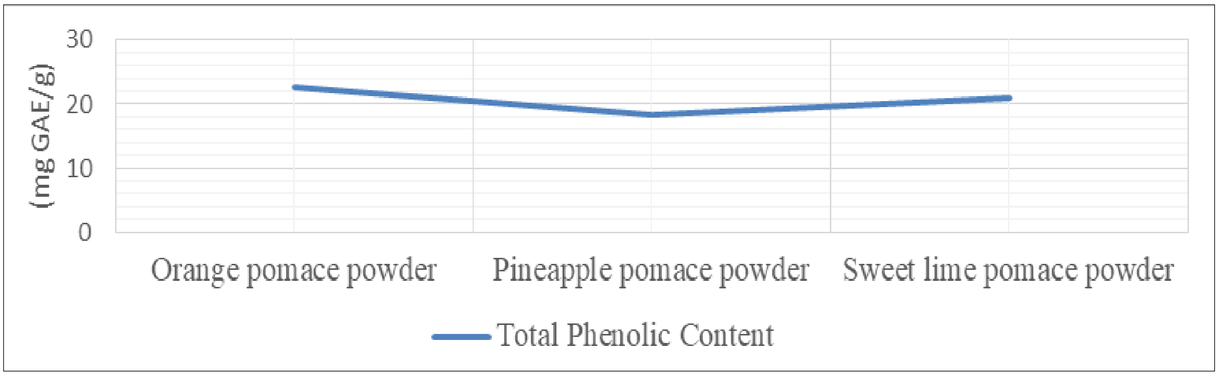

Fig 4: Total Phenolic content of fruit pomace powders

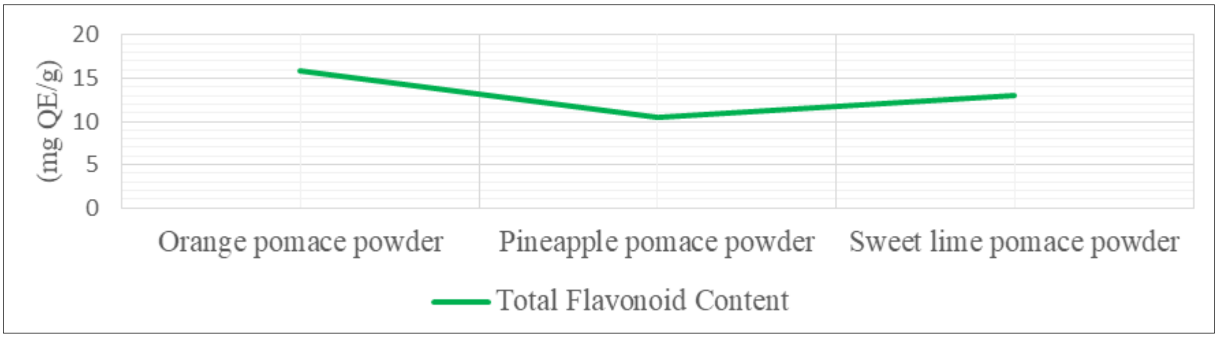

Fig 5: Total Flavonoid Content of fruit pomace

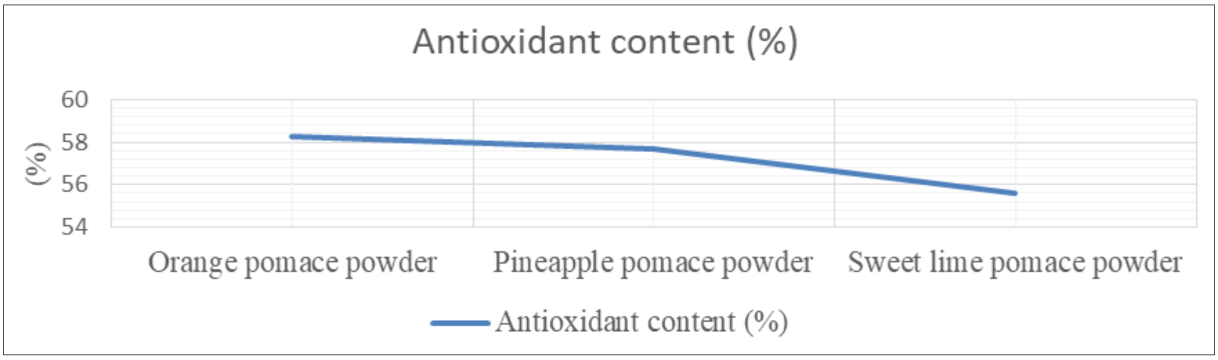

Fig 6: Antioxidant content of fruit pomace powders

Conclusion

The present study demonstrated that orange, pineapple, and sweet lime pomace powders are nutritionally valuable and functionally promising by-products of fruit processing. All three pomaces exhibited low moisture content, appreciable levels of minerals and macronutrients, dietary fibre, and useful functional properties, confirming their suitability for conversion into stable powdered ingredients. Pineapple pomace showed the highest carbohydrate content, sweet lime exhibited comparatively higher fat content, and orange pomace demonstrated the highest total phenolic and flavonoid contents, indicating superior bioactive and antioxidant potential. The higher water absorption capacity of citrus pomaces further highlights their potential for incorporation into fibre-rich food formulations. Therefore, systematic valorization of these fruit-processing residues can reduce waste generation while providing sustainable sources of nutrients, dietary fibre, and bioactive compounds. The powders have potential applications in bakery products, beverages, functional foods, and other value-added food formulations, although further product development and sensory studies are recommended to determine their optimum incorporation levels and consumer acceptability.

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