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Waste to Wealth: Assessing the Sensory and Functional Properties of Fruit Peel Blends Towards Sustainable Nutrition

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Abstract

This study aimed to formulate and compare the sensory and functional properties of nine fruit peel blends designed as dietary additives. The study was experimental; nine fruit peels were processed into three primary blends: orange–lemon–mandarin (OLM), pineapple–cucumber–green apple (PCG), and watermelon–guava–red apple (WGR). Each blend was produced in three variations (A, B, and C). Before analysis, the peels were cleaned, dried, debittered, and ground into powder. Laboratory analyses followed AOAC standard methods, and data were statistically analysed using ANOVA in SPSS version 20.0, with significance set at $p<0.05$. Sensory evaluation revealed significant differences ($p<0.05$) in taste, with scores ranging from 3.60±0.49 for OLMB to 5.87±0.38 for PCGC. Aroma ratings were statistically similar across samples. The WGRB variant achieved the highest overall acceptability, whereas OLMB and WGRC recorded the lowest (4.20±0.62). Solubility varied from 10.5±0.02% (WGRC) to 16.8±0.04% (PCGB), and PCGB exhibited the highest water absorption capacity at 3.3±0.01 ml/g. Research shows that fruit peels are rich in micronutrients and antioxidants, hence these blends can enhance the nutritional value of food systems and help reduce food waste. These findings demonstrate consumer acceptability of the novel fruit peel blend additives.

Keywords: food waste, fruit peels, sustainability, sensory properties, functional properties

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Introduction

The rising global morbidity and mortality rates linked to malnutrition have necessitated the search for sustainable nutrition solutions. Non-communicable diseases (NCDs) have become a major global health concern, contributing substantially to the disease burden in both developed and developing nations (WHO, 2020). As the leading cause of death worldwide, NCDs are responsible for 41 million fatalities each year, accounting for 71% of total global deaths (Bigna & Noubiap, 2019); this is associated with a high level of lifestyle changes. In addition to changes in tobacco use and physical activity, significant changes are also observed in dietary patterns due to Nutrition transition, and these are contributing greatly to the current situation (Piernas et al., 2016). Although premature mortality from NCDs is declining in most countries, for most the pace of change is too slow to achieve SDG target 3.4 (Bennett et al., 2018). Furthermore, nutrition is a key modifiable factor which is known to impact pregnancy outcomes, growth patterns, and the immune development of both the foetus and infant (Bartick et al., 2017). Adopting healthy eating habits has been linked to the prevention of weight-related issues, non-communicable diseases, and micronutrient deficiencies. While the search for solutions to the global problem of hunger and malnutrition is on, the issue of food waste also calls for concern. According to Kumar et al. (2020), the alarming rate of food waste generation (estimated at one-third of all food produced) has sparked a growing interest in the recovery and utilisation of nutritious components from food waste resources. Mabilu et al. (2025) report that fruit and vegetable peels, along with meat bones constitute a significant portion of food waste in the hospitality industry. Addressing this issue involves redistributing surplus meals, avoiding excess stocking of perishable foods (like vegetables) and exploring innovative ways to repurpose excess food (Lefadola et al., 2023). Fruit peels, in particular, are a substantial contributor to food waste, with millions of tons discarded annually. Fruit peels have been found to be rich in bioactive compounds, dietary fibre, and essential nutrients, making them a valuable resource for sustainable nutrition. However, the functional and sensory properties of fruit peel blends remain largely unexplored (Hussain et al., 2022). The current focus on plant-based diets have led to different parts of plants being studied and exploited. Plants produce many secondary metabolites that serve various functions, including providing defence mechanisms from microbial and pest attacks, helping them to adapt to different types of harsh environments, and providing them with the potential to resist biotic and abiotic stress (Onyenweaku et al., 2024). In a wide range of natural plant metabolites, phenolic compounds have recently gained significant attention, due to their anticlotting, antimutagenic, anti-inflammatory, antidiabetic, and antioxidant properties, which are related to their ability to decrease cancer development and the risk of developing cardiovascular diseases (Tungmunnithum et al., 2018). During the processing of fruit and vegetables which are common sources of natural bioactive compounds, many byproducts like the fruit cores, seeds, peels, and pomaces are disposed of; this accounts for up to 25% to 30% of waste for this entire class of food (Ayala-Zavala et al., 2011). These byproducts are reported to possess a remarkable and sometimes higher content of valuable phytochemical compounds compared to the traditionally exploited fruit parts; thus, they can be applied in food product formulation and fortification based on their consumer acceptability and physicochemical properties (Hernández-Carranza et al., 2019). Sensory evaluation is critical in evaluating the acceptance of food products. Consumers will not incorporate a product into their diets if it is not appetising and acceptable to them, regardless of how nutritious it is reported to be. Sensory attributes, particularly flavour, as well as health considerations significantly impact consumer acceptability, consumption, and purchasing behaviour. Fernqvist et al. (2024) suggest that consumer attitudes toward new fruit products are shaped by product quality, the nutritional value, perceived health benefits, and actual flavor/taste. Spence (2015) defines taste as a proximal sense that requires direct contact between food and the tongue's receptors to assess its quality. More specifically, taste encompasses the perception of fundamental flavours - sweet, sour, bitter, salty, and others - detected by gustatory receptors primarily in the oral cavity (Spence et al., 2010). Food flavour is usually said to be a product of both taste and smell (odour) of the food or product. This study therefore investigated the sensory and functional properties of nine fruit peel blends, exploring their potential as a nutritious dietary additives/ food ingredient. By assessing the sensory and physicochemical characteristics of the fruit peel blends, this research sought to contribute to the development of sustainable nutrition solutions, reduce food waste, and promote the health and wellbeing of consumers.

Literature review

Nutritional and health benefits of fruit peels

The focus on plant-based diets to reduce the problem of malnutrition and chronic diseases have brought about a lot of research into the nutrient and antioxidant composition of many plant foods (Onyenweaku et al., 2024) which are primarily classified as fruit and vegetables. Studies have shown that peels from fruits such as citrus fruits, apples, bananas, and pomegranates exhibit strong antioxidant, anti-inflammatory, and antimicrobial properties, which can help in reducing the risk of diet-related NCDs (like cardiovascular diseases, diabetes, and certain cancers). Fruit peels are frequently thrown away as waste both at the household level and in food processing industries, yet they possess significant health benefits due to their high concentrations of dietary fibre, bioactive compounds, and essential nutrients. Singh et al. (2022) reports that citrus fruit peels – like many others - are high in antioxidants, vitamins, minerals, and polyphenols, which have been linked to preventing disease and promoting general health. Similarly, Jabri-Karoui & Marzouk (2014) asserts that citrus peels are rich in flavonoids and vitamin C, which enhance immune function and reduce oxidative stress. Apart from citrus peels, banana peels have also been found to contain significant concentrations of potassium, magnesium, and serotonin, which function in blood pressure regulation and mood enhancement (Emaga et al., 2007). In addition, fruit peels also improve gut health because of their high dietary fibre content, which aids in digestion and guards against gastrointestinal issues (Ajila et al., 2007; Ferreira et al., 2018); for example, pectin and polyphenols found in apple peels have been associated with reduced cholesterol levels and improved gut microbiota composition (Ferreira et al., 2018; Wolfe et al., 2003). Furthermore, Tungmunnithum et al. (2018) reports that fruit peels have bioactive substances such flavonoids, carotenoids, and phenolic acids which exhibit anti-inflammatory, antibacterial, and anticancer properties, thus making them useful for functional food applications. Fruit peels are still discarded in most cases despite their proven health benefits due to lack of knowledge, a false perception of safety (with regards antinutrient content), and their restricted use in food products. Regarding antinutrient levels, research reports that most fruit peels contain compounds like tannins, saponins and hydrogen cyanide (HCN) in levels which are safe and not toxic to the body in any way (Onyenweaku & Kesa, 2024). Instead, certain processing methods such as drying/heating can reduce anti nutrient content and increase the concentration of certain desirable compounds in the fruit peels. Chen et al. (2011) confirms that drying or heating of citrus peels at high temperature significantly increases the level of an important class of flavonoids called flavonols (such as kaempferol and rutin), when the orange peels are dried at 100°C.

Integrating fruit peels into food systems for sustainability and waste reduction

The integration of fruit peels into food systems is a promising strategy for sustainability by reducing food waste and enhancing food production. As concerns about food security and the environment increase, researchers have sought for innovative solutions such as adding powdered fruit peels to baked goods, dairy substitutes, and functional drinks. Numerous studies have also been conducted on their usage as natural food preservatives because of their antibacterial qualities (Mokbel & Hashinaga 2005; Rymbai et al., 2023; Singh et al., 2022). Fruit peels are valued in the food manufacturing process, which promotes resource efficiency and reduces waste, thereby supporting global sustainability goals; their use in animal feed and biodegradable packaging further highlights their benefits for the environment and the economy (Zhang et al., 2024). Gustavsson et al. (2011) asserts that the food businesses globally produce considerable fruit waste, with peels constituting a significant portion of discarded byproducts from the agricultural sector. Food waste exacerbates environmental deterioration, encompassing greenhouse gas emissions and soil contamination, so rendering the sustainable use of fruit peels an essential approach for waste minimisation and economy improvement. The incorporation of fruit peels into food products in industries can enhance food sustainability while reducing the environmental impact of food production. One key strategy for integrating fruit peels into food systems is fortification of processed foods. Peels from citrus, mango, and apple are now being incorporated into flour, juices, and bakery products, enhancing nutritional value and fibre content (Quitral et al., 2025). For example, mango peel powder has been used to enrich bread and biscuits, increasing antioxidant capacity and sensory acceptability (Ajila et al., 2007). Citrus peel extracts are also being utilised in natural food preservatives, replacing synthetic additives due to their antimicrobial and antioxidant properties (Rymbai et al., 2023). Furthermore, fruit peels contribute to sustainable livestock feed production, reducing reliance on traditional feed sources while promoting agricultural waste utilisation (Albuquerque et al., 2016). The extraction of pectin, essential oils, and bioactive compounds from fruit peels supports their use in food packaging, pharmaceuticals, and cosmetics, further promoting renewable innovation (Al-Ashaal & El-Sheltawy, 2011). Despite these remarkable advancements, challenges in integrating fruit peels into food systems persist, including food safety concerns, consumer perception, and standardisation of processing techniques. It is important to develop efficient processing methods,

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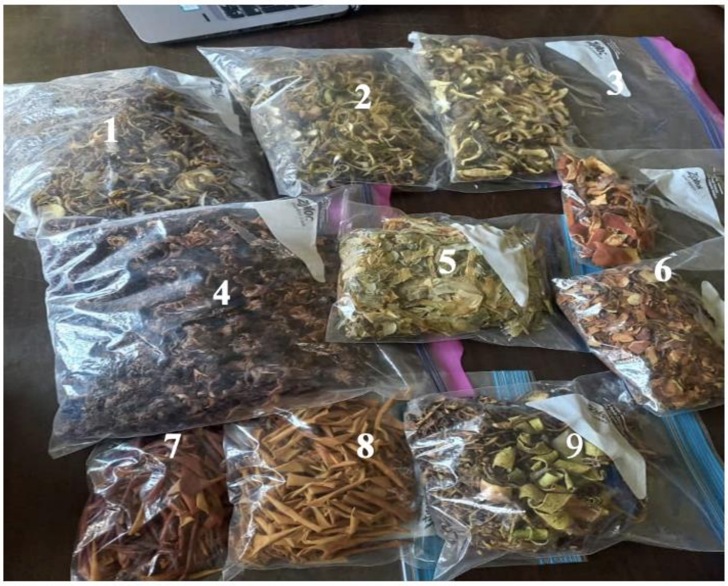
improve sensory characteristics of the peels, and increase consumer awareness; these will enhance the acceptance and use of fruit peels as sustainable dietary additives/food ingredients.

Factors affecting consumer acceptability of food products

Consumer acceptability of a food product is largely dependent on its sensory attributes. Sensory qualities (taste, aroma, texture, and appearance), nutritional value, health beliefs, cultural preferences, and market trends all have an impact on food product acceptability among consumers. Recent studies highlight the importance of clean-label ingredients, sustainability claims, and functional benefits in influencing customer preferences (Asioli et al., 2017). Furthermore, marketing methods such as product labelling, branding, and social influence purchasing decisions. Sensory evaluation remains an important determinant, as many consumers value flavour and texture over nutritional claims. Consumer acceptability of food products is influenced by multiple sensory, psychological, and socio-economic factors, which determine their willingness to purchase and consume a product. Lawless & Heymann (2010) assert that sensory attributes such as taste, aroma, texture, and appearance play a crucial role in food acceptance, as they shape the first impression and overall eating experience. Studies suggest that natural colour variations, bitterness, or unfamiliar textures in food products, particularly those enriched with unconventional ingredients like fruit peels, may impact consumer preferences (Deliza et al., 2003). According to Fernqvist et al. (2024), psychological and cultural elements, as well as sensory qualities, have a considerable influence on food choices. Familiarity, perceived health benefits, and personal ideas about food safety and sustainability all have an impact on consumer purchases. For example, consumers who are more aware of functional foods are more likely to accept goods containing bioactive components from fruit peels, but others who are inexperienced with such uses may be hesitant due to neophobia (Tuorila & Hartmann, 2020). Additionally, price, accessibility, and branding strategies play a role in product acceptability. Consumers may reject sustainable food innovations if they perceive them as too expensive or difficult to integrate into daily diets (Asioli et al., 2017). Effective marketing strategies, educational campaigns, and transparent labelling can enhance consumer trust and promote the adoption of functional foods enriched with fruit-derived compounds (Baker et al., 2022). While consumer acceptability remains a challenge for novel and sustainable food products, addressing sensory preferences, affordability, and awareness barriers can increase market success and long-term adoption.

Methods

This study utilised an experimental design with a quantitative approach. This study was conducted in Calabar, Cross River State, Southern Nigeria. The majority of samples were obtained from local markets and a few were sourced directly from farmers in the area. Approximately 3 kg of fully matured fruit samples were collected from local markets and local farmers. The samples included citrus fruits - orange (*Citrus sinensis*), lemon (*Citrus limon*), and mandarin (*Citrus reticulata*); tropical fruits - pineapple (*Ananas comosus*), watermelon (*Citrullus lanatus*), and guava (*Psidium guajava*); temperate fruits - green apple (*Malus domestica* – golden) and exotic red apple (*Malus domestica* – red delicious); as well as cucumber (*Cucumis sativus*). In order to ensure accurate results, all the fruits were purchased fresh and whole, and special care was taken to select only those free from visible blemishes and bruises. Ripe fruits were used immediately for analysis to prevent spoilage. The fruits underwent some preparation procedures prior to final analyses. First, they were sorted and thoroughly washed under running water to eliminate any surface dirt, debris, or contaminants, then drained. Next, the fruits were carefully peeled using a scraper or a sharp knife to ensure that no fruit pulp or albedo (the spongy white layer found in citrus fruits) was included. The resulting peels were then dried in an oven at 50°C to remove excess moisture and subsequently stored in airtight, clearly labelled Ziploc bags. Finally, a de-bittering process was performed on the dried peels to eliminate any bitter compounds present in the peels.



Legend

1 – Orange peels

2 – Watermelon peels

3 – Lemon peels

4 – Pineapple peels

5 – Cucumber peels

6 – Mandarin peels

7 – Red apple peels

8 – Green apple peels

9 – Guava peels

Figure 1: A cross-section of the dried fruit peels used to formulate the blends

The debittering process began with the samples being immersed in a 2 g/100 mL sodium bicarbonate ($NaHCO_3$) solution at a 1:50 ratio. They were allowed to soak for 45 minutes before being boiled for one hour. Once boiled, the samples were cooled, filtered, and then dried at 80°C, following the method described by Manjarres-Pinzon et al. (2013). After drying, the de-bittered peels were finely ground using a Binatone (BLG 620) blender set at 3000 rpm, ensuring a uniform powder that minimised variability in moisture content for subsequent chemical analyses. Finally, the fruit peels were weighed and carefully formulated into blends as outlined in Table 1, taking into account the regional availability and popularity of these peels.

Table 1: Formulation of the fruit peel blends

BLENDS	% BY WEIGHT OF FRUIT PEELS		
CITRUS – OLM	Orange	Lemon	Mandarin
OLMA	80	10	10
OLMB	70	20	10
OLMC	60	30	10
PCG	Pineapple	Cucumber	Green apple
PCGA	80	10	10
PCGB	70	20	10
PCGC	60	30	10
WGR	Watermelon	Guava	Red apple
WGRA	80	10	10
WGRB	70	20	10
WGRC	60	30	10

The sensory evaluation was conducted using a 9-point hedonic scale (Addo-Preko et al., 2023) with a panel of 15 members. The panel comprised both academic and non-academic staff from the Department of Human Nutrition and Dietetics. Coded samples were distributed to the panellists, who assessed the colour, flavour, aroma, texture, and overall acceptability of each sample. This evaluation was performed in the Department's testing room. Each attribute was rated using the 9-point hedonic scale (9HPS), with the scale defined as follows: 9 - Extremely desirable; 8 - Very much desirable; 7 - Moderately desirable; 6 - Slightly desirable; 5 - Neither desirable nor undesirable; 4 - Slightly undesirable; 3 - Moderately undesirable; 2 - Very much undesirable; 1 - Extremely undesirable. To minimise carry-over effects, each panellist rinsed their mouth with water after sampling each product. The evaluations were carried out for the nine powdered fruit peel blends and the results were recorded in the sensory evaluation forms given to the panellists. The study samples were presented in clean, dry saucers for assessment. After sampling each powdered fruit peel blend, the panellists recorded their ratings on the printed 9-point hedonic scale. The 9PHS was developed decades ago by (Peryam & Pilgrim, 1957).

Determination of functional properties

Emulsion capacity

Using the procedure described by Ige et al. (1984), the emulsion capacity of the samples was determined. Two grams of protein was dissolved in water (40 mL) in an Erlenmeyer flask; then stirred for 15 minutes at a speed of 1,000 rpm using a 1.5-inch magnetic stir bar - forming a slurry. Subsequently, 10 mL of corn oil was gradually introduced over a 5-minute period while maintaining the stirring rate at 1000 rpm; stirring continued for another minute after the complete addition of the oil. The resulting mixture was then poured into a centrifuge tube, before it was heated at 85°C in a water bath for 15 minutes. Stirring continued occasionally before it was cooled in a 25°C water bath for 15 minutes. After cooling, the tube containing the sample was centrifuged at 3,000 rpm until the volume of oil separated from the emulsion remained constant. The extent of oil separation was then measured and expressed as the percentage of oil that separated from the emulsion layer.

Solubility

Solubility was measured according to the method reported by Adeleke & Odedeji (2010). A small quantity (1 g) of sample was put in a centrifuge, before it was mixed with 50 mL of distilled water. This was heated for 15 min at 90°C, while being shaken frequently during heating so as to prevent the powdered sample from clumping. The tube, with its content, was centrifuged at 3,000 rpm for 10 min. Finally, the resulting supernatant was decanted soon after centrifugation then dried to constant weight; the weight of the sediment was also noted.
Solubility = weight of solid after drying x 100.

Swelling index/ capacity

For measurement of swelling capacity, the procedure described by Ukpabi & Ndimele (1990) was adopted. Up to ten (10) grams of the powdered fruit peel blends was measured into a graduated measuring cylinder (300 ml) and the volume noted.

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Afterwards, 150ml of distilled water was added to the sample; the cylinder was then swirled before it was allowed to stand for 4 hours. At the end of the procedure, the final volume after swelling was recorded. Percentage swelling was calculated as:

$$\%\text{ Swelling capacity} = \frac{\text{Final volume (after soaking)} - \text{Initial volume (before soaking)}}{\text{Initial volume}} \times \frac{100}{1}$$

Water absorption capacity (WAC)

For this parameter, the method of Onwuka (2018) was employed. One (1) gram of each powdered fruit peel blend was weighed into conical, graduated centrifuge tubes before the addition of 10ml of water to the weighed sample. This was mixed thoroughly, then the sample was allowed to stand at room temperature for 30 minutes before it was centrifuged at 5,000 rpm for 30 minutes. After this, the volume of free water was recorded directly from the graduated centrifuge tube. Absorption capacity of the samples were expressed as gram of oil or water absorbed per gram of sample.

Calculation:

$$\text{Water absorption capacity (ml/g)} = \frac{\text{(Volume of oil/water used} - \text{volume of free oil/water)}}{\text{Weight of sample}} \times \frac{100}{1}$$

Statistical analysis

Laboratory results were statistically analysed using SPSS version 20.0. To compare analytical values and assess differences across groups, one-way ANOVA was employed. Results are reported as mean ± SEM based on three determinations, with statistical significance set at $p<0.05$ (95% confidence level). Mean scores for sensory evaluation of the powdered fruit peel blends - assessing aroma, colour, taste, texture, and overall acceptability - were calculated from the 9-point hedonic scale data using Microsoft Excel. Ethical clearance for this research was obtained from the School of Tourism and Hospitality Research Ethics Committee with reference number - 21STH08.

Results

Sensory properties of the fruit peel blends

The sensory evaluation of the organoleptic properties of the powdered fruit peels is reported in Table 1. The nine fruit peel blends generally recorded average scores on the 9HPS. The scores for aroma were statistically similar ($p>0.05$) with values ranging from 4.80 ± 0.48 (OLMB) to 6.20 ± 0.41 (WGRA). A similar trend was observed for the colour/appearance ratings for the samples. In terms of taste, all the nine blends had significantly different scores with PCGC having the most liked taste (5.87 ± 0.38) while OLMB had the least preferred taste (3.60 ± 0.49). The WGRB blend had the highest texture rating, and this was significantly higher than the others. Most importantly, WGRB had the highest overall acceptability (OA) score of 5.87 ± 0.48, whereas OLMB and WGRC had the lowest OA score (4.20 ± 0.62).

Table 1: Sensory properties and overall acceptability of the blends

Samples	Aroma	Colour	Taste	Texture	Overall Acceptability
OLMA	4.87 ± 0.50^{a}	5.80 ± 0.30^{a}	4.53 ± 0.56^{a}	5.07 ± 0.62^{a}	4.80 ± 0.74^{a}
OLMB	4.80 ± 0.48^{a}	5.47 ± 0.32^{a}	3.60 ± 0.49^{b}	4.47 ± 0.65^{b}	4.20 ± 0.66^{a}
OLMC	5.40 ± 0.42^{a}	5.93 ± 0.41^{a}	4.14 ± 0.51^{c}	6.40 ± 0.47^{c}	4.50 ± 0.57^{a}
PCGA	5.87 ± 0.41^{a}	6.13 ± 0.38^{a}	5.43 ± 0.53^{d}	5.50 ± 0.49^{d}	4.40 ± 0.42^{a}
PCGB	5.60 ± 0.38^{a}	6.13 ± 0.36^{a}	5.53 ± 0.31^{e}	5.40 ± 0.42^{e}	5.60 ± 0.40^{a}
PCGC	5.80 ± 0.57^{a}	6.20 ± 0.28^{a}	5.87 ± 0.38^{f}	6.40 ± 0.35^{f}	5.00 ± 0.51^{a}
WGRA	6.20 ± 0.41^{a}	5.60 ± 0.35^{a}	5.13 ± 0.36^{g}	5.33 ± 0.40^{g}	5.07 ± 0.44^{a}
WGRB	5.93 ± 0.41^{a}	6.60 ± 0.38^{a}	5.60 ± 0.24^{h}	6.80 ± 0.41^{h}	5.87 ± 0.48^{a}
WGRC	6.13 ± 0.39^{a}	6.33 ± 0.34^{a}	5.80 ± 0.49^{i}	5.47 ± 0.42^{i}	4.20 ± 0.62^{a}

Values are expressed as mean ± SEM, n = 15. Values in the same column with different superscripts are significantly different at $p<0.05$

Functional properties of the fruit peel blends

Figure 2 presents the functional attributes of the nine samples (OLMA, OLMB, OLMC, PCGA, PCGB, PCGC, WGRA, WGRB, WGRC), namely emulsion capacity (EC), solubility, swelling index (SI), and water absorption capacity (WAC).

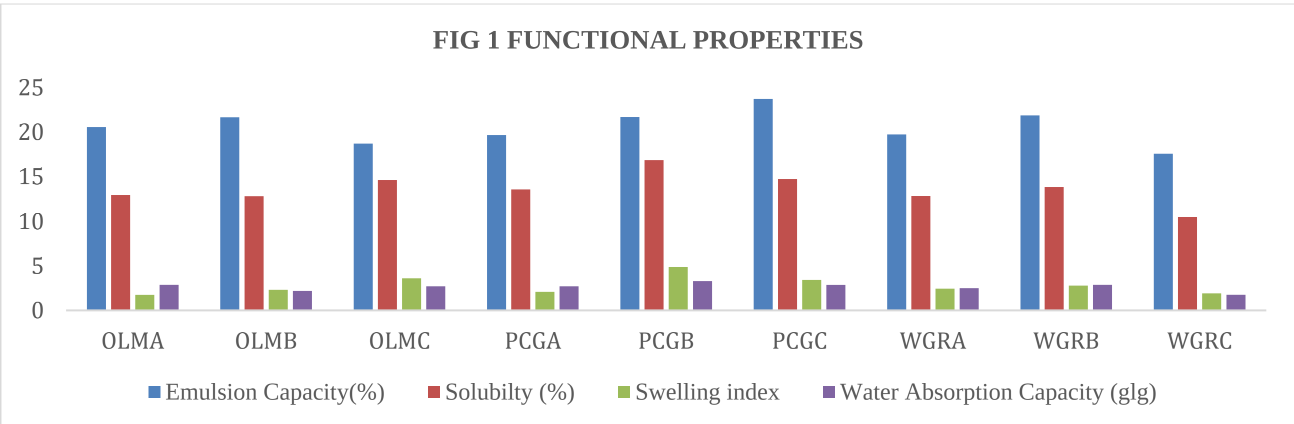

Figure 1: Functional properties of the blends

Emulsion capacity varied significantly across the nine blends, with PCGC recording the highest value of 23.7 ± 0.08 %, while WGRC had the least EC value (17.6 ± 0.03 %). The PCGB blend was the most soluble in water (16.8 ± 0.04%) and this value was significantly higher ($p<0.05$) than the others, with WGRC being the least soluble (10.5 ± 0.02 %). The samples also exhibited significant difference in their swelling indices, with PCGB having the highest SI value of 4.8 ± 0.04, followed by OLMC - 3.6 ± 0.01, while OLMA recorded the lowest SI value of 1.7 ± 0.03. Again, the PCGB blend showed the highest WAC (3.3 ± 0.01 ml/g), significantly ($p < 0.05$) exceeding all other samples; while WGRC had the lowest WAC value (1.8 ± 0.02 ml/g). Overall, PCGB exhibited notably higher functional properties, particularly in solubility, SI, and WAC. On the other hand, WGRC consistently recorded the lowest values across most of the functional parameters.

Discussion

The results of this study show the organoleptic and sensory properties of nine fruit peel blends which were formulated from nine fruits. Previous studies such as Feumba et al. (2016), Ghasemi et al., (2009), Onyenweaku & Kesa (2024), have reported that many fruit peels are rich in essential nutrients and possess useful antioxidant properties. This study opted to prepare the different fruit peels in blends to enhance their taste and improve micronutrient content, exploiting their complementary nutritional profiles for a richer product. Following some literature review, the peels in this study were first de-bittered before analyses. This process not only took out the bitter compounds that may be present in some of the peels, from the sensory results, it also gave the fruit peels a bland taste. The results of the sensory evaluation of ten fruit peels in the initial phase of this study where the fruit peels were analysed singly and without de-bittering, showed higher acceptability scores than those of this current research. This process of de-bittering removed certain unique flavours and tastes which made the first batch of fruit peels more appealing to consumers than these current blends. Therefore, it would be advised that only fruit peels with high concentration of bitter compounds should be de-bittered in order to allow them retain their natural appealing flavours. The citrus fruit peels (orange and lemon – not de-bittered) recorded the highest OA scores in the preliminary aspect of this study. In the same vein, citrus peels, particularly those from orange and lime, have been investigated for their organoleptic properties. Singh & Mishra (2022) compared orange peel powder (OPP) and sweet lime peel powder (SLPP) based on morphological and sensory characteristics. Their findings revealed that, while both powders had similar morphological characteristics, OPP had a smoother texture than the rougher SLPP. Sensory evaluation found that OPP obtained higher colour and flavour ratings, indicating increased acceptance of orange peel in food applications. The functional qualities of citrus peel powders also play an important role in their incorporation into foods systems. Dias et al. (2020) evaluated the physicochemical properties of peels from pineapple, orange, yellow passion fruit, and avocado. Their findings showed that orange and pineapple peels had pleasant scents that intensify with longer drying times. This is in agreement with the findings from this study as many of the sensory panelists noted the citrus blends had pleasant smells especially when de-bittering was not carried out. Notably, passion fruit peel powder showed outstanding water absorption and swelling properties, showing its potential as a dietary hydrocolloid. These qualities are critical for increasing texture and moisture retention in numerous food products. In this study, the PCGB blend exhibited the highest WAC although the values were not so high, showing that it could be successfully incorporated into food systems like dry pastry snacks which do not require high WAC. WAC is important in consistency and bulking of products, as well as in baking applications (Iwe et al., 2016).

However, not all fruit peels have a naturally pleasant flavour. The black plum peel, for example, has sensory qualities such as colour, flavour, firmness, adhesiveness, and spreadability that influence customer acceptance. Mohammadi-Moghaddam & Firoozzare (2021) asserts that discriminant analysis has proved that these properties significantly affect the approval of goods containing black plum peel. Food colour is an important sensory attribute, which can considerably promote acceptability. The fruit peel blends had a good appearance as appraised by the panelists. Regarding texture, once dried properly and milled with an efficient blender, the fruit peels attain a smooth consistency which would not negatively affect any food system they are incorporated into – except liquids like fruit juice which would depend on the peels dissolvability. Lee et al. (2023) report that varying levels of citrus peel powder in confectionaries influenced the texture, colour, and overall acceptability of the product, highlighting the importance of increasing peel concentrations to achieve desirable sensory qualities. The organoleptic qualities of fruit peels have a considerable impact on customer acceptance and possible applications in the food industry. Findings show that certain peels, like mandarin, are more acceptable when ground into powders and mixed into culinary preparations. On the other hand, banana peels have lower OA, indicating the necessity for careful selection and processing methods to boost their sensory appeal (Onyenweaku et al., 2024). In a scoping review by Baker et al. (2022), five categories of acceptability determinants discovered were: product characteristics, socio-demographic characteristics, psychological characteristics, behavioural characteristics, and physico-chemical characteristics. All this play a huge role in how people will respond to a novel product. Lastly, the growing demand for sustainable foods, increased awareness of the role of nutrition in health, and evolving societal trends present avenues for developing innovative food products. However, from an early age, people prefer familiar foods. Research now indicates that personal disposition plays a significant role in responses to novel foods like these fruit peel blends. Factors such as food neophobia, and related traits have been identified as key barriers to the acceptance of new dietary alternatives. As stated by Tuorila and Hartmann (2020), "successfully launching novel foods require a deep understanding of product perception and the consumer traits that determine rejection or acceptance".

Conclusion

There is a growing need for sustainable solutions to the problem of malnutrition on one hand, and on the other hand, efforts should be made to reduce food wastes and the economic loss that follows. While these fruit peels are of significant nutritional value, their sensory properties are important for consumer acceptability. People generally appreciate food and food additives/ingredients based on factors such as taste, aroma, appearance. The fruit peel blends formulated in this study were generally acceptable but may have scored higher on the 9-point hedonic scale if they were not subjected to the de-bittering process. The WGRB (watermelon-guava-red apple) blend had the highest overall acceptability score, although PCGC (pineapple-cucumber-green apple) blend was the most liked in terms of taste. The physicochemical analysis suggests that these fruit peel blends possess functional properties suitable for integration into various food systems such as smoothies, juices and even baked products - to enhance their nutritional value as well as antioxidant content. This food 'fortification' process using fruit peels is applicable both at household level as well as in the food and hospitality industries where food waste is a big challenge. Based on the findings of this study and data from previous related research, it is suggested that: food industries producing juices and smoothies should be advised not to waste the peels from the fruits they process. They should find ways to re-incorporate them into the juices and smoothies as the peels are rich in antioxidants. Also, agricultural companies and farmers should learn to process their fruit peels into sprinkles that can be sold in order to reduce waste and generate additional income.

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