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# Nutritional and sensory properties of processed edible fruit peels: minimising fruit wastes.

**Eridiong O. Onyenweaku[1*], Hema Kesa[1] & Alex K. Tchuenchieu[1]**

[1]Food Evolution Research Laboratory, School of Tourism and Hospitality, College of Business & Economics, University of Johannesburg, South Africa.

*Corresponding author: Eridiong Onyenweaku (PhD)

*E-mail:* eridiongo@uj.ac.za

Tel: +2348037217115

ORCID: https://orcid.org/0000-0001-6691-8269

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**ABSTRACT**

Food insecurity is currently a global challenge and malnutrition is increasing. Efforts are being made to improve nutrition and health using plant-based foods. Fruit peels constitute a major waste recording significant nutrient loss. This study aimed at comparing the nutrient content and organoleptic properties of ten edible fruit peels namely: orange, mango, pineapple, banana, lemon, mandarin, red apple, cucumber, guava, and pawpaw. An experimental approach was used; laboratory analyses were carried out to determine the proximate content of the dried, powdered fruit peels using AOAC standard methods. Sensory evaluation of the peels individually, then in meat sauce was carried out using a 9-point hedonic scale. Quantitative data were analysed using Microsoft excel. Pawpaw peels had significantly ($p<0.05$) higher ash content (11.07±0.04%) than the others with mango peels recording the least (1.69±0.01%). Fibre ranged from 1.23±0.01% (pineapple peels) to 24.80±0.15% (cucumber peels). Mandarin peel was the most generally accepted both singly (7.40±0.35) in the meat sauce (7.10±0.40). Banana peels were the least appealing both singly (4.40 ±0.44) and in meat sauce (5.00±0.68). Consequently, it is recommended that they could be utilized for production of food supplements, and as food additives, which would reduce the amount of fruit wastes while combating malnutrition.

Keywords: fruit peels, dietary additives, food wastes, nutrition, sensory properties

## 1. Introduction

Research has shown that healthy diets have an important role in preventing both chronic and infectious illnesses. It has been reported that numerous chronic and degenerative illnesses, including atherosclerosis, ischemic heart disease, diabetes mellitus, cancer, aging, immunosuppression, neurological disorders, and others, are primarily caused by oxidative stress (Young & Woodside, 2001). Many plant species and their different parts (leaves, stem, fruits, etc.) have been discovered to have substances with antioxidant qualities. These substances consist of carotenoids, phenols, flavonoids, and vitamins and minerals.

The incidence and prevalence of non-communicable diseases (NCDs), including diabetes, obesity, cancer, stroke, and hypertension, have been rising, according to recent figures (WHO Regional office of Africa, 2014). According to WHO (2015), NCDs are the main cause of death across the world. Meanwhile, it is predicted that 80% of diabetes, stroke and premature heart disease may be prevented. In studying the aetiology of certain diseases, Rajendran *et al*. (2014) report that "reactive oxygen species (ROS) in human bodies include peroxyl radical, superoxide anion radical ($\cdot O_2^-$), hydrogen peroxide, hydroxyl radical, hypochlorous acid, singlet oxygen, and nitric oxide radical". During respiration, ROS, including $\cdot O_2^-$ and hydroxyl, are inevitably formed as a result of aerobic metabolism. The body uses ROS for a variety of functions, one of which is signal transduction of inflammation in response to pathogen infection (Hancock *et al*., 2001). On the other hand, lipid peroxidation and protein or nucleic acid denaturation brought on by an excess of reactive oxygen species (ROS) can readily harm cells or tissues. Serious effects on metabolism as a whole can result from this damage (Schieber & Chandel, 2014), which can lead to a host of clinical symptoms like cancer, obesity, heart disease, arthritis, and arteriosclerosis.

Antioxidative defence systems are the most efficient way to stop and reduce the activity of free radicals, which are the source of oxidative stress. Antioxidants are compounds with the ability to disrupt the chain reaction of free radicals. Some of these antioxidants are either vitamins such as Vitamin A, C and E or they are minerals such as selenium, zinc and copper. The therapeutic possibilities of medicinal plants as nutraceuticals that can improve health and wellbeing, have garnered increased attention recently (Pourmorad *et al*., 2006). As one of the Millennium Development Goals - sustainable health and wellbeing, there is an increasing need to prevent illness and enhance health. Functional foods and nutraceuticals which offer additional physiologic benefits apart from nutrition, are becoming popular.

To give information on the possible applications of certain plants in the management and treatment of specific medical diseases, an evaluation of the chemical composition of plant food components is required. Before an in-depth study of the micronutrients and possible antioxidants present in the fruit peels, it is necessary we carry out a proximate analysis of the fruit peels to know the macronutrient content. These fruit peels may be used to boost the nutritional value of foods when included as dietary additives. This will also go a long way to reduce fruit waste both in households and in the hospitality industry.

Furthermore, sensory evaluation is quite key in determining the acceptability of food products to consumers. No matter how potent a product is, if it is not palatable and appealing to consumers, it will not be incorporated into their diets. Bauer described the sensory properties of many tropical fruits, with a focus on flavour notes and flavour compounds. Sensory quality is crucial in evaluating cultivars for both fresh consumption and the processing industry. Colour, taste, flavour, and texture are important quality attributes for fresh consumption (Bauer, 2000). One of the most significant quality attributes of processed foods is their flavour and odor; instrumental methods of assessing these qualities exist, but subjective or human evaluation techniques are often more appropriate and sensitive (Kabir and Sidhu, 2012). Taste and aroma are the primary components of the overall sensation of flavour (Salunkhe *et al*., 1991); while taste and aroma are well integrated in their contribution to the overall flavour, aroma is frequently thought to play a dominant role in flavour (Goof and Klee, 2006; Balwin, 2008). The sensory quality of fruits has become a major determinant of consumers' purchase. The sensory quality of fruits (as a whole) involves a range of attributes such as sweetness, acidity, aroma, firmness, and colour. The sensory properties of fruits depend on many factors, including variety, genetics, picking date, and postharvest handling and storage methods. However, the genotype is probably the most critical among these factors (Kabir and Sidhu, 2012).

Consumer acceptability and, consequently, their consumption and purchasing behavior are heavily influenced by sensory factors, especially flavour, and health considerations. Prosinska and Bartels (2007) suggested that a consumer's attitude toward a new fruit product, or fruit innovation, is influenced by domain-related factors such as quality, perceived health benefits, as well as expected and actual flavour.

Hence, this is a preliminary study to ascertain the nutrient content of ten fruit peels and also their organoleptic properties – as consumed directly and when added to meat sauce.

## 2. Methodology

This research design was experimental and a quantitative approach was employed.

**Sample Collection and Preparation**

About 3kg each of fresh and matured samples of mango (*Mangifera indica*), cucumber (*Cucumis sativus*), lemon (*Citrus limon*), orange (*Citrus sinensis*), pawpaw (*Carica papaya*), banana (*Musa paradisiaca*), guava (*Psidium guajava*), red exotic apple (*Malus domestica*), Mandarins (*Citrus reticulata*), and pineapple (*Ananas comosus*) fruits were collected from local markets before being properly identified by a botanist. To ensure accurate results, extra care in selecting fruits that were free from visible blemishes and bruises. The fruits were purchased at different stages of ripeness, with some being unripe and others being fully ripe. The unripe fruits were allowed to naturally ripen at room temperature, while the ripe fruits were used immediately for analysis.

Prior to analysis, the fruits were prepared by first sorting, then washing them thoroughly under running water to remove any surface dirt, debris, or other contaminants before draining. The fruits were then peeled carefully using a scraper to ensure that no pulp remained on the peel. Finally, the fruit peels were air-dried in a well-ventilated room to remove excess moisture then ground to obtain a fine powder using a Binatone (BLG 620) blender at 3000rpm. These steps were taken to ensure that the samples were in a consistent state for analysis and to minimize any potential variability in the results due to differences in moisture content or other factors.

**Laboratory analyses**

*Determination of Moisture Content*

Moisture content was determined using the standard method of Association of Official Analytical Chemists (AOAC, 2010).

*Determination of Crude Protein Content*

Protein content was determined using the Kjeldahl method (AOAC, 2010).

*Determination of Fat Content*

The fat content was determined using Soxhlet extraction method according to AOAC (2010).

*Determination of Carbohydrate*

The Carbohydrate was determined by difference according to AOAC (2010), as follows:

% Carbohydrates = 100 - (% moisture + % fat + % ash + % protein + % crude fibre)

*Determination of Energy value*

The values obtained for protein, fat and carbohydrate were used to calculate the energy value of the samples using the Atwater formula as described by FAO (2003) and the value is expressed as kilocalories (kcal):

Protein content (%) = P

Fat content (%) = F

Carbohydrate content (%) = C

Energy value (Kcal/100g) = P x 4.0 + F x 9.0 + C x 4.0

**Sensory evaluation**

The sensory evaluation was conducted using a 9-point hedonic scale (Wichchukit and O'Mahony, 2015), and a panel consisting of 20 members. The sensory evaluation panel was made up of both academic and non-academic staff of the Department of Human Nutrition and Dietetics. The coded samples were given to the panelists to assess for colour, flavour, fragrance, texture, and general acceptability. The process was carried out in the Department's testing room. Each sensory evaluation was rated on a 9-point hedonic scale which was graded thus:

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 eliminate the carry-over effect, each panelist was given water to rinse their mouth after trying each product. The panelists evaluated both powdered fruit peels and the powdered fruit peels in meat sauce. The dried fruit peels were presented in clean dry saucers and the powdered fruit peels in soup were presented in clean, transparent soup bowls alongside teaspoons for tasting.

Preparation of the meat sauce

It was prepared using goat meat. The procedure was as follows -

1. The cut goat meat was washed in clean tap water and put in a pot to boil.
2. Water and some seasonings (very little dry pepper – about 1g, salt, onion and bouillon cubes) were added to the meat and allowed to cook for 20 minutes.
3. After cooking, the meat sauce was allowed to cool and 150 mls was dished into 5 separate soup bowl; then 5g of each fruit peel was added to the five soup bowls and stirred well.

Teaspoons were given to the panelists to taste the meat sauce for the sensory evaluation. After tasting each powdered fruit peel, the panelists recorded their results on the 9-point hedonic scale which were printed out for each one of them. After that round, they tasted the powdered fruit peels in the meat sauce and also recorded their observations.

**Statistical analysis**

Laboratory results generated from this study were statistically analysed using the Statistical Package for Social Science (SPSS) version 20.0. In order to compare the nutrient values and check for significant difference among groups, one-way analysis of variance (ANOVA) was used. The results were expressed as mean ± SEM for 3 determinations, and statistical significance was accepted at $p<0.05$ (95 % confidence level). Values obtained from the 9-point hedonic scale were used to calculate the mean scores of sensory evaluation for the organoleptic properties of the powdered fruit peels for aroma, colour, taste, texture and general acceptability on MS excel sheet. SPSS version 20.0 was used for ANOVA.

**Figure 1: Dried fruit peels (Attached as a separate file)**

## 3. Results

**Proximate composition and energy values of the edible fruit peels**

The macronutrient content and the calculated energy values for the fruit peels are shown in Table 1. Pawpaw peel had the highest ash content (11.07 ± 0.04%) followed by cucumber peel (7.49 ± 0.01%) and lemon peel (6.83 ± 0.17%) and this was significantly different ($p<0.05$) from the others, with mango peel recording the lowest ash value (1.69 ± 0.01%). Fibre values ranged from as low as 1.23 ± 0.01% (in pineapple peel) to as high as 24.80 ± 0.15% (in cucumber peel). For carbohydrates, mandarin, pineapple, banana, guava and red apple peels had statistically similar ($p>0.05$) values of about 62% while pawpaw peel had the lowest carbohydrate content (about 22%). Pawpaw peel, once again, had the highest protein content (20.05 ± 0.05%) which was significantly higher than that of all the other fruit peels, with orange peel recording the lowest protein value of 4.23 ± 0.12% closely followed by lemon and mango peels (5.49 ± 0.02% and 5.73 ± 0.26%, respectively). The energy values ranged from 250.13 ± 0.66% (cucumber peel) to 459.84 ± 0.01% (mango peel) with lemon, mandarin, pineapple, guava and red apple having statistically similar ($p>0.05$) energy values (about 320kcal).

TABLE 1: Proximate composition (%) of the processed edible fruit peels

| Fruit peels | Moisture | Ash | Fat | Fibre | CHO | Protein | Energy (kcal) |
|---|---|---|---|---|---|---|---|
| Orange | 11.96 ±0.03$^{f}$ | 5.95 ±0.04$^{f}$ | 24.16 ±0.17$^{f}$ | 14.03 ±0.03$^{d}$ | 39.78 ±0.23$^{b}$ | 4.23 ±0.12$^{a}$ | 371.51 ±11.91$^{d}$ |
| Cucumber | 13.95 ±0.04$^{g}$ | 7.49 ±0.01$^{i}$ | 7.03 ±0.03$^{c}$ | 24.80 ±0.15$^{f}$ | 34.69 ±0.20$^{b}$ | 12.27 ±0.04$^{f}$ | 250.13 ±0.66$^{a}$ |
| Lemon | 8.18 ±0.02$^{a}$ | 6.83 ±0.17$^{h}$ | 16.82 ±0.09$^{e}$ | 14.73 ±0.15$^{d}$ | 47.98 ±0.25$^{c}$ | 5.49 ±0.02$^{b}$ | 322.35 ±25.81$^{bc}$ |
| Mango | 15.79 ±0.04$^{i}$ | 1.69 ±0.01$^{a}$ | 33.67 ±0.17$^{g}$ | 9.77 ±0.15$^{c}$ | 33.37 ±0.58$^{b}$ | 5.73 ±0.26$^{b}$ | 459.84 ±0.01$^{e}$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pawpaw | 15.12 ±0.07[h] | 11.07 ±0.04[j] | 13.03 ±0.02[d] | 18.32 ±0.16[e] | 22.37 ±0.29[a] | 20.09 ±0.05[h] | 287.48 ±1.04[ab] |
| Mandarins | 10.49 ±0.01[b] | 4.19 ±0.01[d] | 1.86 ±0.03[a] | 8.52 ±0.12[bc] | 64.02 ±1.89[d] | 8.41 ±0.01[c] | 316.23 ±0.35[bc] |
| Pineapple | 11.57 ±0.03[e] | 3.87 ±0.03[c] | 1.75 ±0.01[a] | 1.23 ±0.01[a] | 63.87 ±2.68[d] | 12.43 ±0.02[f] | 327.63 ±10.79[b] |
| Banana | 10.39 ±0.01b | 6.41 ±0.01[g] | 5.68 ±1.97[bc] | 5.63 ±2.21[b] | 60.39 ±3.71[d] | 13.62 ±0.08[g] | 338.01 ±0.83[cd] |
| Guava | 10.79 ±0.01[c] | 4.61 ±0.01[e] | 3.83 ±0.01[ab] | 8.52 ±0.04[bc] | 62.41 ±0.05[d] | 9.77 ±0.01[d] | 323.37 ±0.07[bc] |
| Red apple | 11.31 ±0.01[d] | 3.47 ±0.03[b] | 4.31 ±0.03[ab] | 7.61 ±0.01[bc] | 62.62 ±0.03[d] | 10.67 ±0.01[e] | 332.24 ±0.30[bcd] |

Values are expressed as mean ±SEM, n = 3. Samples with similar symbols are homogenous.

**Sensory evaluation of organoleptic properties of the powdered fruit peels**

The sensory evaluation of the organoleptic properties of the powdered fruit peels is reported in Table 2. Mandarin fruit peels was the most generally acceptable (7.40±0.35) and this was statistically different from the others; banana peels on the other hand, was the least acceptable (4.40±0.44) and this was statistically similar ($p>0.05$) to the acceptability levels of pawpaw, guava and red apple peels. Mean scores for aroma ranged from 4.35±0.45 (banana peels) to 7.20±0.42 (lemon peels) and both were quite statistically different at $p<0.05$. For colour, mandarin peels scored highest (7.75±0.24) closely followed by lemon peels (7.50±0.37), with banana peels recording the lowest (4.70±0.44). Pawpaw peel recorded the highest score for taste (6.90±0.38) and this was statistically similar ($p>0.05$) to the taste scores for mango and lemon peels; banana peel had the least acceptable taste (4.10±0.42) closely followed by guava peel (4.85±0.41). Mean values for texture ranged from 5.85±0.25 (pineapple peel) to 7.30±0.45 (cucumber peel).

Table 2: Sensory evaluation of organoleptic properties of the processed fruit peels (mean scores)

| Fruit peels | Aroma | Colour | Taste | Texture | General Acceptability |
|---|---|---|---|---|---|
| Orange | 7.00±0.45[d,e] | 7.20±0.39[d,e] | 5.90±0.46[b] | 6.00±0.30[a] | 6.90±0.57[c] |
| Cucumber | 5.50±0.31[a,b] | 7.40±0.22[d,e] | 5.10±0.38[a,b] | 7.30±0.45[c] | 5.70±0.54[a,b,c] |
| Lemon | 7.20±0.42[e] | 7.50±0.37[d,e] | 6.80±0.42[c] | 6.80±0.47[a,b,c] | 6.10±0.78[a,b,c] |
| Mango | 5.90±0.64[b,c, d] | 5.40±0.62[a,b,c] | 6.80±0.49[c] | 7.10±0.35[b] | 6.60±0.60[b,c] |
| Pawpaw | 5.80±0.51[b,c, d] | 5.60±0.34[a,b,c] | 6.90±0.38[c] | 6.90±0.31[a,c] | 4.80±0.83[a] |
| Mandarin | 6.90±0.26[c, d,e] | 7.75±0.24[e] | 6.00±0.38[b] | 7.10±0.22[b,c] | 7.40±0.35[c] |
| Pineapple | 5.45±0.26[a,b] | 6.00±0.21[b,c] | 5.60±0.30[b,c] | 5.85±0.25[a] | 5.75±0.39[a,b,c] |
| Banana | 4.35±0.45[a] | 4.70±0.44[a] | 4.10±0.42[a] | 6.35±0.36[a,b,c] | 4.40±0.44[a] |
| Guava | 5.70±0.29[b,c] | 6.45±0.29[c, d] | 4.85±0.41[a,b] | 6.30±0.26[a,b,c] | 4.95±0.47[a,b] |
| Red apple peels | 5.55±0.29[a,b] | 5.10±0.35[a,b] | 5.70±0.30[b,c] | 6.20±0.26[a,b] | 4.80±0.47[a] |

Values are expressed as mean ± SEM, n =10.
Values in the same column with different superscripts are significantly different ($p<0.05$).

**Organoleptic properties of the powdered fruit peels in meat sauce**

Table 3 shows the mean scores for the sensory evaluation of the powdered fruit peels dissolved in meat sauce. Out of the ten fruit peels dissolved as additives in the meat sauce, mandarin peel (7.10±0.40) was the most generally accepted closely followed by cucumber and pineapple peels. Pawpaw peels in meat sauce was the least acceptable with a mean score of 5.00±0.68. Mango peel had the highest aroma mean score (7.80±0.29) and this was statistically similar ($p>0.05$) to that of orange and cucumber peels. Guava peel scored the lowest (6.00±0.36) for aroma. Mean score for colour ranged from 5.00±0.28 (banana peel) to 7.50±0.43 (orange peel) which was the highest. Cucumber peel had the most appealing taste (8.00±0.30) closely followed by mango peel (7.60±0.37) with guava peel scoring lowest (5.50±0.38). According to the panelists, mango peel had the finest texture (7.60±0.31) closely followed by pawpaw peel (7.40±0.27), and these were statistically different ($p<0.05$) from red apple texture mean score (4.85±0.41) which was the least.

Table 3: Organoleptic properties of the powdered fruit peels in meat sauce (mean scores)

| Fruit peels in meat sauce | Aroma | Colour | Taste | Texture | General Acceptability |
|---|---|---|---|---|---|
| Orange | 7.50±0.43[b,c,d] | 7.50±0.43[c] | 6.80±0.71[a,b,c] | 6.30±0.62[b,c] | 6.30±0.60[a,b] |
| Cucumber | 7.50±0.31[b,c,d] | 6.90±0.35[b] | 8.00±0.30[c] | 6.20±0.55[b,c] | 6.60±0.56[a,b] |
| Lemon | 7.00±0.80[a,b,c] | 7.20±0.57[c] | 6.30±0.79[a,b] | 5.90±0.71[a,b] | 6.00±0.80[a,b] |
| Mango | 7.80±0.29[c,d] | 6.90±0.35[b,c] | 7.60±0.37[b,c] | 7.60±0.31[d] | 6.40±0.75[a,b] |
| Pawpaw | 7.10±0.57[a,b,c] | 7.40±0.34[c] | 6.90±0.78[a,b,c] | 7.40±0.27[c,d] | 5.00±0.68[a] |
| Mandarin | 7.20±0.19[a,b,c, d] | 6.95±0.21[b,c] | 6.75±0.22[a,b,c] | 6.35±0.27[b,c,d] | 7.10±0.40[b] |
| Pineapple | 6.60±0.34[a,b,c, d] | 6.50±0.28[b,c] | 5.85±0.29[a] | 6.00±0.38[a,b] | 6.55±0.37[a,b] |
| Banana | 6.25±0.33[a,b] | 5.00±0.28[a] | 5.95±0.33[a] | 5.35±0.27[a,b] | 5.55±0.45[a,b] |
| Guava | 6.00±0.36[a] | 6.00±0.35[a,b] | 5.50±0.38[a] | 6.55±0.33[b,c,d] | 5.65±0.42[a,b] |
| Red apple | 6.15±0.36[a] | 5.15±0.39[a,c] | 5.80±0.32[a] | 4.85±0.41[a] | 5.15±0.5[a] |

Values are expressed as mean ± SEM, n =10.
Values in the same column with different superscripts are significantly different ($p<0.05$).

## 4. Discussion

The proximate analysis shows the macro nutrient content of the ten fruit peels in this study. The low moisture content (as a result of dehydration before powdering) is similar to the results reported by Feumba *et al*. (2016) who also carried out a similar study on the chemical composition of some fruit peels. After air drying and milling, mango peel had the highest moisture content while lemon peel had the least; this can be attributed to the nature of these fruit peels. Due to the low percentage of moisture in the powdered fruit peels, they may be preserved for a longer duration, because the threat of molds is greatly decreased in the absence of, or low moisture content. Analysis of moisture - which is crucial for life maintenance, is one of the most commonly used metrics to predict how a food product will be processed and how long it will last on the shelf (Akinsanmi *et al*., 2015); it is also used as a measure of stability and susceptibility to microbial contamination. Table 1 also shows that pawpaw peel recorded the highest ash concentration next to cucumber peel, with mango peel having the least value. This is very similar to that reported by Feumba *et al.* (2016) where pawpaw and banana peel had the highest ash among the fruit peels they studied. Similarly, Omutubga *et al*. (2012) recorded low ash values for mango peel like that of this study. The ash content was present in considerable amounts in all the analysed fruits peels. The mineral content of a food is indicated by its level of ash content (Ndife *et al*., 2019). This suggests that pawpaw and cucumber peels may be a very rich source of essential minerals (the second aspect of this work focuses on the analyses of specific micronutrients). The fibre content of cucumber, pawpaw and lemon were highest and this was similar to fibre content reported for pawpaw peel by Feumba *et al.* (2016). The other fruit peels they analysed had slightly higher fibre values than the peels analysed in this study. Pineapple peel had the lowest fibre content probably due to the nature of the peel. Research shows that a high fibre diet may contribute to reduce the risk of cardiovascular diseases, colonic cancers and diabetes. These fruits peels are a valuable source of fibre since they can contribute significantly to the recommended dietary allowance (RDA) of fibre for children (19-25%), adults (21-38%), pregnant (28%) and lactating mothers (29%) (Adamu *et al*., 2016). Generally, the fruit peels are not a rich source of protein but pawpaw and banana peels had significant amounts. Furthermore, pineapple peel and stem contain significant concentrations of the potent enzyme (protein) bromelain, which is another benefit of consuming pineapple peel. As an anti-inflammatory for the sinuses, arthritis, and joint pain, it helps reduce inflammation throughout the body (Cerqueira *et al*., 2020). Legumes and cereals are better sources of protein than fruits. Regarding their carbohydrate and energy values, most of the peels like that of mandarin, pineapple, banana, guava and red apple had considerable carbohydrate content which were similar to values reported by Gbenga-Fabusiwa *et al*. (2022) and Feumba *et al.* (2016). Only pawpaw peel had very low carbohydrate content which may be attributable to its non-sweet nature. Mango peel had the highest energy value possibly due to its high fat content while cucumber peel had the lowest energy value (has more of moisture and fibre). This means that these peels, when incorporated into diets in adequate amounts can contribute significantly to the RDA for energy.

The ten fruits peels under study were evaluated for sensory parameters such as colour, taste, aroma, texture and general acceptability. There were differences in these parameters between the powdered fruit peels and the different fruit peels in meat sauce; they varied in palatability and acceptability as reported by the 20-man panel. The aroma of the fruit peels in meat sauce was significantly higher than that of just the fruit peels. The high mean score for aroma recorded by the fruit peels in meat sauce can be attributed to the ingredients such as goat meat, onion, and bouillon cubes used in the preparation of the meat sauce. This result is in line with the earlier report of Chacko and Estherlydia (2013), who reported a high aroma value for orange peel in jam. Aroma is a crucial component of cuisine. When food smells good, the taste buds are excited and the body is prepared to accept the meal; nevertheless, when food smells bad, the body may reject the food completely before it is even consumed. The citrus fruits – orange, lemon and mandarin had more appealing colour both singly and when added to the meat sauce. This is possibly due to the bright colours of ripe citrus fruits which can be quite attractive. In addition, orange and pawpaw peels in meat sauce recorded the highest colour mean value and this may be attributed to the xanthophyll pigment which is present in coloured plastids in chromoplast. This pigment consists of fat-soluble carotenoids pigment which is responsible for the yellow, orange or red colour in orange and pawpaw fruit. The results of the present study are in line with the earlier reports of Singh and Mishra (2022), who reported a high colour value for orange. Food colour is an important sensory property, which can considerably enhance acceptability. According to Spence (2015), taste refers to “the proximal sense that requires direct contact of food with stimuli on the tongue to determine the quality of the ingested food.” Taste specifically refers to “the perception of sweet, sour, bitter, salty, and the other basic tastes, which are detected by the gustatory receptors found primarily in the oral cavity” (Spence *et al*., 2010). The results of this research reveal that the taste of the fruit peels in meat sauce was better than just the powdered fruit peels, with cucumber dried fruit peels in meat sauce recording the highest taste value. This agrees with the recent report of Atchaya and Divya (2023), who also reported a high taste value for cucumber peels. Pawpaw, mango and lemon fruit peels had the highest taste mean scores but not when dissolved in the meat sauce. This suggests that there is an interplay between food condiments and spices that contribute to the final taste of foods. Due to the effect of improved palatability, little modifications in food's flavour can have a comparatively great influence on its acceptance. For example, when bland food is enhanced in flavour by the addition of salt, spices, herbs, and seasonings, individuals are more likely to accept and eat most of the food that they had previously disliked (Romagny *et al*., 2017).

On a general note, the sensory evaluation of the fruit peels indicates variations in the sensory attributes of the various fruit peels (at $p<0.05$). The aroma (flavour), colour, taste, texture, and general acceptability of the citrus fruit peels – orange, mandarin and lemon, was significantly higher compared to all the other fruit peels. This strongly suggests that food additives made using citrus fruit peels will be quite appealing and acceptable to consumers. This will not only reduce fruit wastes but also improve the nutritional value of the foods they are added to.

## 5. Conclusion

The challenge of the double burden of malnutrition is also on the rise globally. People do not have access to healthy and adequate diets. This, in addition to poor lifestyle habits, is increasing the prevalence of NCDs. Fruits have been found to be rich in essential nutrients that help to build the body's immune system and fight diseases, but sometimes the peels of the fruits are discarded whereas it has been discovered that most peels are rich in antioxidants. This study showed that the peels of fruits can add significant nutritional value to foods when used as additives; the fruit peels were found to be good sources of minerals (ash), fibre and even protein. The processed fruit peels were also quite acceptable based on the 9-point hedonic scale with mandarin peels being the most liked, while banana peels had least acceptability. The use of these fruit peels as dietary additives will significantly reduce food wastes both in households and in the hospitality industry.

**Conflict of Interest**: None

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