Sustainable Tea Innovation: Harnessing Orange Rind and Pineapple Core for Functional Beverage Development

ABSTRACT

Aims: This study focuses on the physicochemical, phytochemical and sensory analysis of tea produced from orange rind and pineapple core.
Study design: Five variations of orange rind and pineapple core powder in 100:0, 75:25, 50:50, 25:75, and 0:100 ratios were the experimental lots, labelled A to E, respectively, and a commercial green tea labelled sample F was used as a control.
place and duration of study:oranges and pineapple fruit were bought from the railway market in Makurdi, Benue state of Nigeria. a standard commercial green tea was purchased from a supermarket in Makurdi Benue State of Nigeria
Methodology: Various analytical techniques were employed to assess the tea's physicochemical properties, anti-nutrient, phytochemical content and antioxidant capacity. Sensory evaluations were also conducted to gauge consumer acceptance and preference.
Results: The physicochemical properties of the tea ranged from pH (4.7-5.6), TTA (0.62-1.00%), TSS (8.45-10.47 °Brix), Brix/acidity ratio (6.27-13.69). The anti-nutrient content ranged as follows: alkaloids (0.083-0.113%), oxalates (0.032-0.048%), phytates (0.001-0.003%), and tannins (0.0005-0.0124%). The phytochemical content was as follows: total flavonoids (5.45-7.61 mgQE/g), total phenols (1.36-3.98 mgGAE/g). The samples also demonstrated significant antioxidant activity as follows; FRAP (2.23-8.79 mgAAE/g), H2O2 scavenging ability (4.23-10.11%). Importantly, sensory results showed that all the herbal tea samples were well-received and accepted by the panellists, indicating their potential in the market.
Conclusion: The tea samples produced demonstrated great potential for its use as a functional beverage and as a substitute for other tea brands, given its improved functional characteristics. This study explored the potential applications of orange and pineapple by-products in sustainable product development

*Keywords: [*functional beverage, orange rind, pineapple core, antioxidant, infusion*]*

1. INTRODUCTION

In an era where sustainability and innovation are paramount, the world of beverage development stands at a crossroads, seeking new avenues to create products that are not only delicious but also environmentally responsible and addressing the global well-being preference that is important to multiple of the United Nations' Sustainable Development Goals (SDGs) notably emphasized in Goal 2 (Zero hunger)[1],[2]. Tea is a popular beverage consumed worldwide due to its refreshing taste and potential health benefits [3]. It is commonly made from the leaves of the Camellia sinensis plant. However, there has been growing interest in exploring alternative sources for tea production such as herbal teas[4].

Orange rind, which is the primary waste fraction in the production of orange juice, contains flavonoids associated with antioxidant activity[5]. Dried orange rind has shown higher antioxidant activity compared with lemon and grapefruit [6]. Pineapple is essential in fruit and juice products such as juice concentrates, jams, squash, jellies and pickles. Processing of pineapple generates waste in the form of peel, core, trimmings crown; Core alone contributes 20% of the total waste generated by the pineapple processing industry and is normally disposed of as such[7]. Pineapple residues are rich in many bioactive compounds such as ferulic acid,vitamins A and C, hence proofs to be a good source of several beneficial properties [8]. This groundbreaking endeavour delves into the utilization of underutilized orange rind and pineapple core to craft a functional beverage that not only tantalizes the taste buds but also aligns with a greener, more sustainable future.

2. MATERIAL AND METHODS

2.1 Sourcing and Preparation of Raw Material

Oranges and pineapple fruit used in this study were bought from the railway market in Makurdi, Benue State. A standard commercial green tea was purchased from a supermarket in Makurdi Benue State of Nigeria. Figure 1 and Figure 2 show the processing of orange rind powder and pineapple core powder, respectively, while Table 1 shows orange rind and pineapple core powder blend formulation.

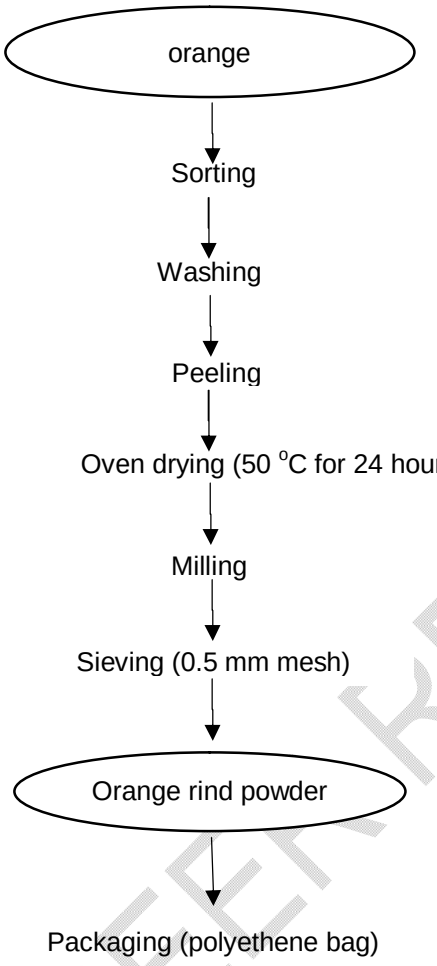

Figure 1. Flow chart for the production of orange rind powder[9]

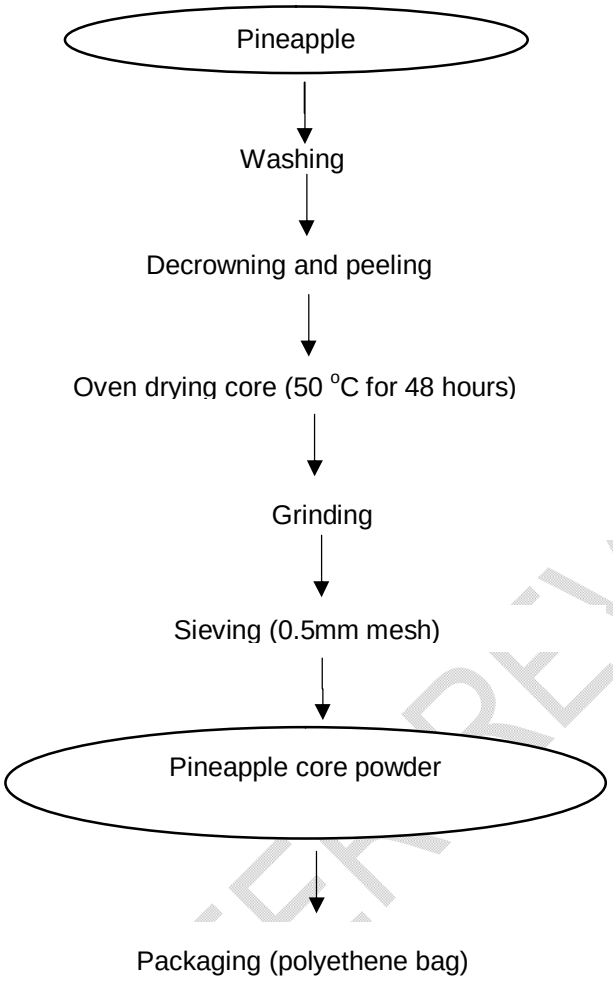

Figure 2. Flow chart for the production of pineapple core powder[10].

Table 1: Formulation of orange rind and pineapple core powder blend

	Ingredient (%)	
Sample	**Orange rind powder**	**Pineapple core powder**
A	100	0
B	75	25
C	50	50
D	25	75
E	0	100
F	Commercial green tea (control)	

2.2 Analytical Methods

2.2.1 Determination of physicochemical properties of the tea samples

2.2.1.1 Determination of pH

The pH was measured at 25°C through a pH electrode connected to an ion analyzer (Hanna Instruments HI98107). Previous to the measurements, the equipment was calibrated with standard solutions of pH 4.01 and 6.86[11].

2.2.1.2Determination of Total Titratable Acidity (TTA)

In sequence with pH measurements, the samples which showed a pH value below 7.0 was submitted to titratable acidity analysis as reported by[11]. NaOH solution (0.1 N) was added to a tea volume of 25 ml until pH 7 was reached. The volume of 0.1N NaOH solution (in millilitres) necessary to achieve a neutral solution was recorded, and it corresponds to the titratable acidity of the tea samples.

2.2.1.3Determination of total soluble solids (TSS)

The tea infusion was dropped on the Lense of a refractometer (Abbe Refractometer) and the corresponding TSS values were recorded according to Kayisoglu and Coskun, 2021[12]

2.2.2Determination of phytochemical and antioxidant activityof the tea samples

2.2.2.1 Determination of total phenols

Folin-Ciocalteu reagent was used to determine the total phenolic content of the tea samples as described byHossain and Rahman, 2011 [13]. Gallic acid was used as a reference standard. A volume of 0.5 mL of the tea infusion was mixed with 1.5 mL of Folin-Ciocalteu reagent and later neutralized with 3 mL of sodium carbonate solution (7.5%, w/v). The reaction mixture was allowed in the dark at room temperature for 30 minutes with intermittent shaking for colour development. The absorbance of the resulting colour mixture (blue) was measured by UV-Vis spectrophotometer (PASCO UV-Vis Spectrometer SE-3607) at 765 nm. The Total phenol content was determined using a linear regression equation obtained from the standard plot.

2.2.2.2Determination of total flavonoid content

Total flavonoid content was determined as reported by [13]. Diluted standard solutions of quercetin and tea extracts (0.5 mL) were mixed with 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminium chloride, 0.1 mL of 1 mol/L potassium acetate and 2.8 mL of distilled water in test tubes. The test tubes were incubated for 30 minutes at room temperature to complete the reaction. The absorbance of the reaction mixture was measured at 415 nm with a UV-visible spectrophotometer (PASCO UV-Vis Spectrometer SE-3607) against blank. The amounts of flavonoid in samples were estimated from a linear regression equation obtained from the quercetin calibration curve, expressed as mg of quercetin equivalent.

2.2.2.3Determination of Ferric Reducing Antioxidant Power (FRAP) of the tea samples

The FRAP of the samples was determined by a method using potassium hexacyanoferrate with slight modification [14]. An aliquot of the tea infusion (0.1 ml) was mixed with 0.2 M phosphate buffer (pH 6.6) and 1% $K_4Fe(CN)_6$ and incubated for 20 min at 50°C followed by precipitation with 10% trichloroacetic acid (TCA). After centrifugation at 3,500 rpm for 15 minutes, the supernatant was diluted with equal volumes of distilled water and ferric reducing capacities of the extracts were checked by adding 0.1% $FeCl_3$. The absorbance was read at 700 nm(PASCO UV-Vis Spectrometer SE-3607) against a reagent blank. Ascorbic acid was used as the reference standard, and results were expressed as ascorbic acid equivalent.

2.2.2.4H2O2 reducing activity

The extent to which the tea produced can scavenge hydrogen peroxides was assayed according to the method described by [15]. A solution of hydrogen peroxide (40mM) was prepared in phosphate buffer (pH 7.4). Infusions from the tea samples (1 mL) were added to a hydrogen peroxide solution (0.6 mL, 40mM). The absorbance of hydrogen peroxide at 230 nm (PASCO UV-Vis Spectrometer SE-3607)was determined after 10 minutes against a blank solution containing phosphate buffer without hydrogen peroxide. The percentage of hydrogen peroxide scavenging activity by the extracts and a standard was calculated as:

$$\% \text{ Scavenged } [H_2O_2] = \frac{Ao - A1}{Ao} \times 100$$

Where A_o is the absorbance of the control, and A1 is the absorbance in the presence of the sample of extracts.

2.2.3Quantification of anti-nutrients in thesamples

Alkaloids were quantified by the gravimetric method described by Rocedure and Nalysis, 2015 [16]. Oxalates were determined by titration method using $KMnO_4$[17]. Phytate content was determined by titration using standard Iron (III) chloride [18]. Tannin content was determined spectrophotometrically according to[19]

2.2.4Sensory evaluation of the tea samples

Sensory evaluation was performed as described byIwe, 2002[20]. A 30-panel member was randomly selected from students and staff of the Department of Chemistry, Benue State University, to perform the organoleptic test. The evaluation was based on a 9-point hedonic scale quality, with nine representing "liked extremely" and one representing "disliked extremely".

2.2.5Statistical analysis

Statistical analysis was done using Statistical Package for Social Science
(SPSS Version 27) computer software. All experiments were conducted in triplicates and reported as mean ± standard deviation. Analysis of variance (one-way ANOVA) was used to ascertain any significant differences in the treatments at a 95% (*P=0.05*) significant level. The Duncan Multiple Range Test (DMRT) was used to separate means.

3. RESULTS AND DISCUSSION

3.1 Results

Table 2: Physicochemical Parameters of the Tea Samples

Sample	A	B	C	D	E	F
Ph	5.6^{a}±0.06	5.3^{b}±0.06	5.1^{c}±0.06	4.9^{d}±0.00	4.7^{e}±0.06	5.4^{b}±0.06
pH*	6.3^{a}±0.06	6.1^{b}±0.12	5.8^{c}±0.15	5.2^{c}±0.06	4.9^{d}±0.10	6.1^{b}±0.06
TTA (%)	0.62^{e}±0.04	0.68^{d}±0.04	0.79^{c}±0.02	0.89^{b}±0.02	1.00^{a}±0.04	0.85^{b}±0.02
TTA* (%)	0.44^{d}±0.02	0.46^{d}±0.04	0.55^{c}±0.02	0.67^{b}±0.03	0.83^{a}±0.00	0.68^{b}±0.04
TSS (^{o}Brix)	8.45^{c}±0.04	8.40^{c}±0.18	9.86^{b}±0.12	10.10^{b}±0.11	10.47^{a}±0.31	5.35^{d}±0.01
TSS* (^{o}Brix)	6.22^{c}±0.10	6.41^{c}±0.26	7.21^{b}±0.01	7.11^{b}±0.12	7.62^{a}±0.13	5.32^{d}±0.08
Brix/acidity	13.69^{a}±0.80	12.32^{b}±0.43	12.49^{b}±0.44	11.41^{c}±0.14	10.44^{d}±0.08	6.27^{e}±0.13
Brix/acidity*	14.24^{a}±0.39	14.01^{a}±0.58	13.00^{b}±0.40	10.60^{c}±0.60	9.16^{d}±0.15	7.81^{e}±0.49

***** Parameters gotten after 8 weeks on the shelf. TTA- total titratable acids, TSS- total soluble solids

Values represent mean ± SD of triplicate determinations. Means in the same row with different superscripts are significantly different at *P=0.05*

Table 3: Phytochemical Composition and antioxidant activity of the tea samples

Sample	Total flavonoids (mgQE/g)	Total phenols (mgGAE/g)	FRAP (mgAAE/g)	H_2O_2 (%)
A	7.55^{a}±0.01	3.42^{b}±0.03	5.37^{b}±0.06	6.31^{b}±0.11
B	7.61^{a}±0.34	3.49^{b}±0.43	4.96^{c}±0.00	5.58^{c}±0.22
C	6.42^{b}±0.00	2.59^{c}±0.07	3.86^{d}±0.06	5.55^{c}±0.01
D	5.48^{c}±0.12	2.31^{c}±0.09	3.80^{d}±0.26	5.52^{c}±0.06
E	5.45^{c}±0.06	1.36^{d}±0.06	2.23^{e}±0.01	4.23^{d}±0.02
F	6.40^{b}±0.12	3.98^{a}±0.02	8.79^{a}±0.03	10.11^{a}±0.00

Values represent mean ± SD of triplicate determinations. Means in the same column with different superscripts are significantly different at $p<0.05$

Figure 3: Antinutritional Composition (%)of theTea Samples

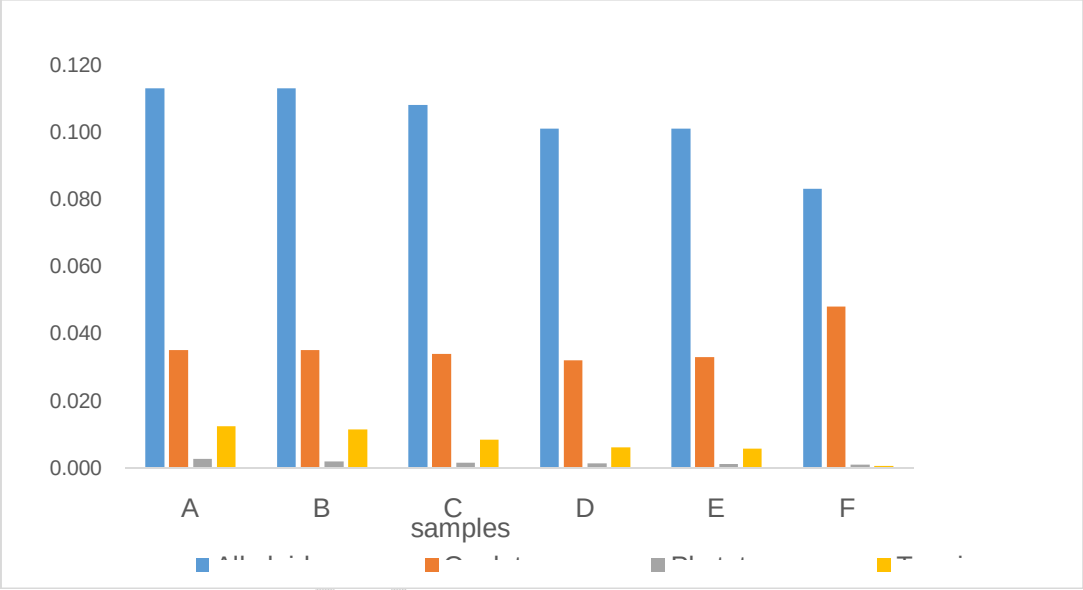

Table 4. Sensory Evaluation of the Tea Samples

Sample	Appearance	Aroma	Taste	Overall Acceptability
A	7.95^{a}±0.76	7.85^{ab}±1.18	7.50^{a}±0.95	8.05^{a}±0.83
B	7.80^{a}±0.83	8.25^{a}±0.72	7.75^{a}±0.85	8.05^{a}±1.00
C	7.55^{a}±0.89	7.45^{b}±0.83	7.60^{a}±0.82	7.65^{a}±0.88
D	7.50^{a}±1.00	7.60^{ab}±0.88	7.80^{a}±0.77	7.95^{a}±0.83
E	7.40^{a}±1.35	7.95^{ab}±1.15	8.00^{a}±1.03	7.70^{a}±1.08
F	8.00^{a}±1.08	6.60^{c}±1.23	6.05^{b}±1.70	6.50^{b}±1.32

Values represent mean±SD of triplicate determinations. Means in the same column with different superscripts are significantly different at *P=0.05*

3.2 Discussion

3.2.1 Physicochemical properties of the tea samples

The pH of the samples ranged from 4.7 to 5.6. There was a significant decrease (at *P=0.05*) in pH as the substitution level of the sample with pineapple core increased. The pH of sample F (control sample) was 5.4. These results show that all the samples were acidic.The low pH of pineapple core compared to that of orange rind complies with the results of[21] who reported a pH of 3.59 in pineapple core and [5]who reported a pH of 4.56 in oven dried orange rinds. The pH of the samples after 8 weeks ranged from 4.9 in sample E (100% pineapple core) to 6.3 in sample A (100% sample E). As observed, there was a significant increase in the pH of the samples after 8 weeks. This could be due to enzymatic and other chemical reactions in the tea samples that might break down the acidic compounds in the samples causing the pH to increase[22].

Rehman *et al*., in 2014[23] reported an increase in pH of fruit juice stored for 30 days and further reported that the increment was due to acid hydrolysis of some polysaccharides into disaccharides. Measuring the pH of tea infusion provide insights into its acidity or alkalinity level. pH can influence the taste profile and flavour balance of tea since different compounds present in tea are more or less soluble at specific pH levels, affecting the overall taste of the tea infusion.

There was a significant increase (*P=0.05*) in TTA as the substitution level of samples with pineapple core increased (from sample A to sample E). This could be due to the high content of citric and malic acid in pineapple core. Citric acid makes up 87% of total acid in pineapple, with malic acid as another significant organic acid [23].

There was a significant increase in the TSS content as the composition of pineapple core powder increased. This could be attributed to the high sucrose, glucose and fructose content of pineapple core which are even twice as high than in the pineapple pulp compared to orange rind [24]. A TSS of 12.0 ^{o}Brix in pineapple core has been reported [24]. The least TSS (5.35 ^{o}Brix) was observed in sample F (commercial green tea), significantly different from the other samples. This is attributed to the low content of sugars in green teas[12]. After 8 weeks on the shelf, the TSS of the samples, except for the control sample, significantly dropped. This drop could be attributed to factors such as temperature, exposure to light, and the presence of enzymes or microorganisms thatcould affect the stability of sugars and other compounds.

The Brix/acidity ratio is a measure of the sweetness-to-acidity balance in a solution, commonly used in the food and beverage industry. It is typically used in the context of measuring the sweetness and acidity of fruit juices, wines and other similar products. Fromthe result, there is a significant decrease in the Brix/acidity ratio from sample A to sample F. This could be attributed to the fact that relative to the acidic content, the sugar content of orange rind is higher than that of pineapple core. This could explain the slightly sour taste of pineapple core even though it is sweet.

3.2.2 Phytochemical composition of thetea samples

The total flavonoid content of the samples ranged from 5.45 mgQE/g - 7.55 mgQE/g. The lowest flavonoid content was observed in sample E while the highest was in sample A. There was a significant decrease in the total flavonoid content of the tea samples as the composition of the orange rind was reduced. This could be due to the high flavonoid content of orange rind compared to pineapple core. A total flavonoid content of 6.40 mgQE/g was observed in the control sample, which was not significantly different from sample C but was significantly different from the other tea samples. Oboh and Omoregie, 2011 reported a total flavonoid content of 10.00 mgQE/g in green tea, which is higher than the one reported in this research[25]The variation might be due to differences in the variety of green tea samples and the protocol of analysis. Flavonoids possess strong antioxidant properties.

The total phenolic content of the tea samples was in the range of 1.36 mgGAE/g - 3.94 mgGAE/g. The least total phenolic content was observed in sample E. In contrast, the highest total phenolic content was observed in sample F. There was a significant decrease in the total phenolic content of the samples as the level of incorporation with orange rind reduced. This result shows that total phenolics are higher in orange rind compared to pineapple core, which is in line with the results of [26]. The phenolic content in the control sample was significantly higher than in the other samples. Oboh and Omoregie, 2011 [25]Reported a phenolic content of 99.90 mgGAE/g in green tea, which showed that green tea is a rich source of total phenols.

The FRAP content of the tea samples ranged from 2.23 mgAAE/g in sample E to 8.79 mgAAE/g. As observed, there was a significant decrease in the FRAP content of the samples as the composition of orange rinds reduced in the samples. This could be due to the high phenolic and flavonoid content and other antioxidant compounds like ascorbic acid in orange rind compared to pineapple core. The antioxidant potential of plants and plant parts is associated with the presence of phenolic compounds, which is due to the presence of one or more hydroxyl groups with the potential to quench free radicals by forming stabilized phenoxy radicals [27]. The highest FRAP content was observed in sample F which was significantly different ($p<0.05$) from the other sample. A FRAP content of 1235.88 mg/g was reported in green tea[25]which showed that green tea has a highferric-reducing power. The result is significantly higher than the one reported in this research, which could be due to the variation in the variety of green tea and the method of analysis used.

The values for the H_2O_2 scavenging activity ranged from 4.23% - 10.11%. There was a significant decrease in the values as the level of orange rind reduced, with sample E having the lowest of 4.23% while sample F having the highest value of 10.11%. H_2O_2 is a reactive oxygen species produced in the body, toxic to the body tissues even at a low concentration of 10 µM. Phenolic compounds or other antioxidants present in samples could donate electrons to H_2O_2, neutralizing it to $2H_2O$. This goes further to highlight that the increase in the hydrogen peroxide scavenging could be due to the myriad of phytochemicals present in orange and pineapple fruit waste [26].

3.2.3 Antinuritional composition of thetea samples

The alkaloid content was between 0.083% in sample F (commercial green tea) and 0.113% in sample A (100% orange rind). There was a significant decrease in the sample's alkaloid content as the samples' orange rind compositionreduced. This could be due to the high content of alkaloids in orange rinds compared to pineapple core. The least alkaloid content of 0.083% was observed in the control sample. Dibanda Romelle *et al*., 2016[26] reported an alkaloid content of 5.44% and 16.19% in fresh orange rinds and pineapple peels, respectively, and this result shows that processing of the orange rinds and pineapple core greatly reduced the alkaloid content of the samples. Alkaloids belong to a class of naturally occurring organic compounds that mostly contain basic nitrogen atoms. Thesecompounds include related compounds withneutral and even weakly acidic properties. Some synthetic compounds of similar structure also belong to the class of alkaloids. They generally possess high levels of bitterness and thus become universal feeding deterrent in plant-herbivores interactions [28].

The oxalate content in the tea samples ranged from 0.033% - 0.048. There was a significant difference ($p<0.05$) between sample F (control) and the other tea samples. Yusuf *et al*., (2017) reported an oxalate content of 1.02 mg/100g of fresh orange rind, and from this result, it can be concluded that processing reduced the oxalate content of the samples. These results show that the oxalate content in the tea samples was generally low, which agrees with the 0.02 mg/100g of oxalate reported in tea [30].

The phytate and tannin content of the samples were generally low, and the results ranged from 0.001% to 0.0027% and 0.0005% to 0.0124%, respectively. The least phytate and tannin content was observed in the control sample, which was significantly different from the other sample. Phytates have been known to decrease the availability of some minerals (calcium, iron, magnesium and zinc) as well as protein; when bound to protein, it induces a decrease in the solubility and functionality of the protein. On the other hand, tannins are considered nutritionally undesirable because they precipitate proteins, inhibit digestive enzymes and affect the utilization of vitamins and minerals. Ingesting large amounts of tannins may result in adverse health effects, such as impaired microbial enzyme activity and forming irreversible as well as reversible complexes with these enzymes [31].

3.2.4 Sensory evaluation of thetea samples

3.2.4.1 Appearance

The mean scores for the appearance of the tea samples ranged from 7.40 in sample E - to 8.00 in sample F. There was a significant difference in the appearance of the tea samples. The highest value (8.00) for appearance was observed in sample F, which indicates “like very much” on the hedonic scale, which was significantly different from all the other samples except for sample A. Amino acids in tea have a significant role in colour production which may be oxidized by catechins resulting in tea liquor colour[30]. The lowest value (7.40) for appearance was observed in sample E. Pineapple core and orange rind contain phenolic compounds, including flavonoids and phenolic acids that influence the overall colour of the samples. The extent of the Maillard reaction and the resulting MRPs during the drying process of orange rind and

pineapple core could affect the final colour of the samples. Colour is known as the only quality on which consumers can base their purchasing decisions (Surkan*et al*., 2009).

3.2.4.2 Aroma

The mean scores for the aroma of the tea samples ranged from 6.60 - 8.25. Sample B was the most preferred in terms of aroma. There was, however, no significant difference (p> 0.05) observed between samples A, B, C, D, and E, but there was a significant difference between sample F (control) and the other samples. This could be due to the solid aromatic flavourof orange rind and pineapple core. The lowest mean score value (6.60) for aroma was observed in sample F, which indicated “like slightly” on the hedonic scale. This result is in line with that of Onyeneke, (2021) who reported a mean score value of 5.60 for aroma in green tea.

3.2.4.3Taste

The mean taste scores ranged between 6.05 in sample F - and 8.00 in sample E. There was a significant increase (*p*> 0.05) in the taste value as the level of incorporation of samples with pineapple core increased. This is because orange rind provides a concentrated citrus aroma and bitterness. In contrast, pineapple core provides a milder sweetness to the samples, hence making sample E the most preferred, as taste is of concern. Sample F showed the lowest value of 6.05, indicating “like slightly” on the hedonic scale, which was significantly different (*p*> 0.05) from the other samples. The taste quality of tea is strongly associated with the amount of thearubigins, theaflavins, amino acids, and catechins present in the tea, which also has a significant contribution to the sensory characteristics of tea [30].

3.2.4.4 Overall acceptability

The overall acceptability mean scores recorded by the tea samples ranged between 6.50 and 8.05, with sample F recording the lowest mean of 6.50, which indicates “like slightly” on the hedonic scale. There was a significant difference (*p*<0.05) in terms of overall acceptability between the tea samples and the control (sample F). Sample B had the highest mean score (8.05). The overall acceptability shows how much or less a product is globally accepted. Acceptability may not always depend solely on the sensory attributes of the product but also on other determinants, such as physiological, behavioural and cognitive factors, related to the consumer (El Dine and Olabi, 2009).

4. CONCLUSION

The present study showed that the physicochemical, phytochemical and Sensory evaluation of herbal tea produced from orange rind and pineapple core has provided valuable insights into these waste products' potential benefits and applications. The study revealed significant levels of bioactive compounds, such as polyphenols, flavonoids, and antioxidants, which contribute to the overall health-promoting properties of the tea. The tea exhibited favourable physicochemical characteristics, including suitable pH, which is desirable for the tea shelf life, and desirable colour, aroma, and taste profiles. These findings suggest that tea derived from the orange rind and pineapple core could be a sustainable and economically viable alternative to traditional tea sources.

REFERENCES

[1] N. Jiménez-Moreno, I. Esparza, F. Bimbela, L. M. Gandía, and C. Ancín-Azpilicueta, “Valorization of selected fruit and vegetable wastes as bioactive compounds: Opportunities and challenges,” *Crit. Rev. Environ. Sci. Technol.*, vol. 50, no. 20, pp. 2061–2108, 2020, doi: 10.1080/10643389.2019.1694819.

[2] L. Nchung, M. O. Eke, C. N. Emmanuel, and N. B. Bongjo, “Assessment of Nutritional and Functional Properties of Complementary Food from Orange-Fleshed Sweet Potato, Soybean and Tropical Almond Seed Composite Flour,” *Eur. J. Nutr. Food Saf.*, vol. 16, no. 2, pp. 13–29, 2024, doi: 10.9734/ejnfs/2024/v16i21384.

[3] B. Narotzki, A. Z. Reznick, D. Aizenbuda, and Y. Levy, “Green tea: A promising natural product in oral health.,” *Arch. Oral Biol.*, vol. 1, no. 57, pp. 429–435, 2012.

[4] C. Ravikumar, “Review on Herbal Teas,” *J. Pharm. Sci. Res.*, vol. 6, no. 5, pp. 236–238, 2014.

[5] H. Bozkir, Y. Tekgül, and E. S. Erten, “Effects of tray drying, vacuum infrared drying, and vacuum

microwave drying techniques on quality characteristics and aroma profile of orange peels," *J. food Process. Eng.*, vol. 13, no. 6, p. 11, 2020, doi: 10.1111/jfpe.13611.

[6] F. I. Kanaze, A. Termentzi, C. Gabrieli, I. Niopas, M. Georgarakis, and E. Kokkalou, "The phytochemical analysis and antioxidant activity assessment of orange peel (Citrus sinensis) cultivated in Greece-Crete indicates a new commercial source of hesperidin," *Biomed. Chromatogr.*, vol. 23, no. 3, pp. 239–249, 2009, doi: 10.1002/bmc.1090.

[7] R. S. Chaurasiya and H. Umesh, "Extraction of bromelain from pineapple core and purification by RME and precipitation methods," *Sep. Purif. Technol.*, vol. 111, pp. 90–97, 2013, doi: 10.1016/j.seppur.2013.03.029.

[8] W. M. Hikal *et al.*, "Pineapple (Ananas comosus L . Merr .), Waste Streams , Characterisation and Valorisation : An Overview," *Open J. Ecol.*, pp. 610–634, 2021, doi: 10.4236/oje.2021.119039.

[9] O. O. Olabinjo, A. S. Ogunlowo, O. O. Ajayi, and A. P. Olalusi, "Analysis of Physical and Chemical Composition of Sweet Orange (Citrus sinensis) Peels," *Int. J. Environ. Agric. Biotechnol.*, vol. 2, no. 4, pp. 2201–2206, 2017, doi: 10.22161/ijeab/2.4.80.

[10] R. Singh, "International Journal of Advanced Research in Biological Sciences Development of fiber enriched bakery products by incorporating fruit pulp waste powder and their acceptability evaluation," *Int. J. Adv. Res. Biol. Sci.*, vol. 3, no. 6, pp. 222–226, 2019.

[11] L. B. F. Lunkes and L. N. Hashizume, "Evaluation of the pH and titratable acidity of teas commercially available in Brazilian market," *RGO - Rev. Gaúcha Odontol.*, vol. 62, no. 1, pp. 59–64, 2014, doi: 10.1590/1981-86372014000100000923.

[12] S. Kayisoglu and F. Coskun, "Determination of physical and chemical properties of kombucha teas prepared with different herbal teas," *Food Sci. Technol.*, vol. 41, no. 1, pp. 393–397, 2021, doi: 10.1590/fst.12720.

[13] M. A. Hossain and S. M. M. Rahman, "Total phenolics, flavonoids and antioxidant activity of tropical fruit pineapple," *Food Res. Int.*, vol. 44, no. 3, pp. 672–676, 2011, doi: 10.1016/j.foodres.2010.11.036.

[14] P. Nobosse, E. N. Fombang, and C. M. F. Mbofung, "The effect of steam blanching and drying method on nutrients, phytochemicals and antioxidant activity of moringa (Moringa oleifera L.) leaves.," *Am. J. Food Sci. Technol.*, vol. 5, no. 2, pp. 53–60, 2017, doi: doi.org/10.12691/ajfst-5-2-4.

[15] B. Sultana, F. Anwar, and M. Ashraf, "Effect of extraction solvent/technique on the antioxidant activity of selected medicinal plant extracts," *Molecules*, vol. 14, no. 6, pp. 2167–2180, 2009, doi: 10.3390/molecules14062167.

[16] I. I. P. Rocedure and F. O. R. A. Nalysis, "Quantitative Evaluation of Anti-nutritional Factors in Mango (Magniferaindica) Fruit," *Int. J. Appl. Sci. Math.*, vol. 2, no. 5, pp. 142–145, 2015.

[17] AOAC, "AOAC," in *Official methods of analysis, Association of Official Analytical Chemists, Washington, D.C., USA.*, 15th Editi., 2010, pp. 807-928.

[18] W. Disseka, M. Faulet, F. Koné, M. Gnanwa, and L. Kouamé, "Phytochemical Composition and Functional Properties of Millet (Pennisetum glaucum) Flours Fortified with Sesame (Sesamum indicum) and Moringa (Moringa oleifera) as a Weaning Food," *Adv. Res.*, vol. 15, no. 6, pp. 1–11, 2018, doi: 10.9734/air/2018/42811.

[19] D. Krishnaiah, T. Devi, A. Bono, and R. Sarbatly, "Studies on phytochemical constituents of six Malaysian medicinal plants.," *J. Med. Plant Resour.*, vol. 3, no. 2, pp. 67–72, 2009.

[20] M. O. Iwe, *Handbook of Sensory methods and analysis.* Enugu, Nigeria: Rojoint Commercial. Services Ltd., 2002.

[21] S. Roha, K. Z. Nadzirah, S. Zainal, A. Noriham, I. Normah, and H. Nadya, "Physico- chemical properties of pineapple variety N36 harvested and stored at different maturity stages," *Int. Food Res. J.*, vol. 20, no. 1, pp. 225–231, 2013.

[22] R. Yoruk and M. R. Marshall, "Physicochemical properties and function of plant polyphenol oxidase: A review," *J. Food Biochem.*, vol. 27, no. 5, pp. 361–422, 2003, doi: 10.1111/j.1745-4514.2003.tb00289.x.

[23] M. A. Rehman, M. R. Khan, M. K. Sharif, S. Ahmad, and F. Shah, "Study on the storage stability of fruit juice concentrates Study on the storage stability of fruit juice concentrates," *Pakistan J. Food Sci.*, vol. 24, no. 1, pp. 101–107, 2014.

[24] B. Cordenunsi *et al.*, "Carbohydrate composition of ripe pineapple (cv. perola) and the glycemic response in humans," *Ciênc. Tecnol. Aliment*, vol. 30, no. 1, pp. 282–288, 2010, [Online].

Available: www.fcf.usp.br/tabela
[25] H. A. Oboh and I. P. Omoregie, “Total Phenolics and Antioxidant Capacity of Some Nigerian Beverages,” *Niger. J. Basic Appl. Sci.*, vol. 19, no. 1, pp. 68–75, 2011, doi: 10.4314/njbas.v19i1.69346.
[26] F. Dibanda Romelle, R. P. Ashwini, and R. S. Manohar, “Chemical Composition of Some Selected Fruit Peels,” *Eur. J. Food Sci. Technol.*, vol. 4, no. 4, pp. 12–21, 2016, [Online]. Available: www.eajournals.org
[27] Y. Lu, T. Khoo, and C. Wiart, “Antioxidant activity determination of Citronellal and crude extracts of Cymbopogon citratus by 3 different methods.,” *Pharmacol. Pharm.*, vol. 5, pp. 395–400, 2014, doi: doi.org/10.4236/pp.2014 .54047.
[28] S. Ee Wei, “Isolation and determination of anti-nutritional compounds from roots and shells of peanut (Arachis Hypogaea),” Universiti Tunku Abdul Rahman, 2011.
[29] K. . O. . Yusuf, O. . M. . Ajeigbe, A. . T. . Oyebo, R. . Y. . Aderinboye, O. . O. . Adelusi, and O. C. . F. . I, “Nutrients and anti-nutrients content of some crop by- products and residues fo ...,” *J. Anim. Prod. Res.*, vol. 29, no. 1, pp. 249–262, 2017.
[30] E. N. Onyeneke, “Quality Evaluation of Different Branded Tea Sold in Nigeria,” *World News Nat. Sci.*, vol. 39, no. 1, pp. 61–75, 2021.
[31] S. Ram, S. Narwal, O. P. Gupta, V. Pandey, and G. P. Singh, *Anti-nutritional factors and bioavailability: approaches, challenges, and opportunities*. Elsevier Inc., 2020. doi: 10.1016/b978-0-12-818444-8.00004-3.
[32] S. Surkan, O. Albani, and L. Ramallo, “Influence of storage conditions on sensory shelf life of yerba mate,” *J. Food Qual.*, vol. 32, no. 1, pp. 58–72, 2009, doi: 10.1111/j.1745-4557.2008.00236.x.
[33] A. N. El Dine and A. Olabi, “Effect of reference foods in repeated acceptability tests: Testing familiar and novel foods using 2 acceptability scales,” *J. Food Sci.*, vol. 74, no. 2, pp. 97–106, 2009, doi: 10.1111/j.1750-3841.2008.01034.x.

APPENDIX
SAMPLE ANALYSIS AND LABORATORY WORK