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Research Article

Storage stability of functional fruit drink supplemented with polyphenols extracted from lemon and mango peels

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ABSTRACT

Use of natural bioactive compounds, especially polyphenols in functional beverages has gained a lot of interest because of the health promoting effects they exhibit and the ability to enhance shelf life. Functional fruit juices include those that contain additional physiologically active ingredients and offer health benefits. Lemon and mango peels are a rich source of phenolic compounds. Fortified functional foods containing lemon and mango peel polyphenolic extract may be used as a preventative & therapeutic alternative measure for several disorders linked to oxidative stress and to provide consumers with a drink that is more nutritious. The goal of the research was to introduce different amounts (2% and 4%) of lemon and mango polyphenols, which were extracted by sonication, into an apple-peach drink. Investigation of the physical-chemical properties, total phenolic content (TPC), and antioxidant activity (DPPH) for a product that was stored at a refrigerated temperature for two months on a fortnight basis. The findings showed that the total soluble solids (TSS), titratable acidity (TA), pH, antioxidant activity and total phenolic contents of apple-peach juices increase after storage. Fruit drink's sensory qualities diminished over the course of a two-month storage period. In conclusion, it was preferable to supplement fruit beverages with 2% polyphenolic extract in order to maintain their physicochemical as well as organoleptic properties. The collected data was statistically analyzed using a two-way ANOVA table. Research aims at the possibility of using lemon and mango peels and similar by-products of the fruit industry to create enhanced instant beverages with desirable attributes such as longer shelf life and nutritional benefits. This approach also not only creates value out of food waste but also meets the shifting trend of clean label and sustainability into the food industry.

Keywords: Food waste; functional fruit drink; peels; polyphenols; Oxidative stress.

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INTRODUCTION

Globally, customers' appetite for nutritious food has increased during the past decade (Bogue et al., 2017). Functional fruit juices include those that contain additional physiologically active ingredients and offer health benefits above and beyond their basic nutritional value. Significance in developing functional foods & drinks is strengthening because of their heightened attributes for consumer health and potential in market (Nazir et al., 2019). Ingesting functional fruit drinks could cut health care costs by roughly 20% (Sun-Waterhouse, 2011). One of the major issues facing contemporary society is oxidative stress. Air pollution, UV rays, smoking and way of life all cause oxidative stress in cells, which is the root cause of many disorders like dermatitis, malignant melanoma, and photo-aging of the skin. Functional fruit drinks have a continual preventative mechanism, which reduces the workload on health sectors (Shahidi, 2004). Beverages are typically regarded to be the best vehicle for enrichment of nutraceuticals to increase nutritious worth (Kausar accounts for 15 to 20% of the fruit weight which goes wasted in processing (Mwaurah et al., 2020).

Lemon peel makes up between 50 and 65 percent of the overall fruit weight (Sharma et al., 2017). The chief lemon peel polyphenol (LPP), Eriocitrin is a yellow, water-soluble antioxidant that is found in large quantities in peel of lemons. Mangiferin & quercetin 3-0-galactoside, two major polyphenols found in mango peel, can prevent or treat cancers such as lungs, brain, colorectal, breast, & spinal cord tumors. According to a pear cultivar, the peel has 25 times more TPC (total phenolic content) and contains more antioxidant than the flesh (Cruz-Bravo et al., 2019).

Polyphenols, which belong to the class of secondary metabolites derived from shikimate, phenyl propanoid, and pentose phosphate pathways, constitute a diverse group of natural compounds found in plants (Borochov-Neori et al., 2009). Phenolic compounds possess a wide range of beneficial properties, such as pathogen resistance, anti-microbial activity, anti-inflammatory effects, cardioprotection, vasodilation, and antioxidant activity (Caruso et al., 2021). Current research strongly supports the role of polyphenols in the prevention of degenerative diseases, particularly cardiovascular diseases, neurodegenerative disorders, and cancer. Polyphenols act as potent antioxidants, combating oxidative stress induced by reactive oxygen species (ROS).

Ultrasound assisted extraction, also termed ultrasonic extraction (20-100 kHz) has been noted to be one of the most innovative and emerging approaches among non-thermal techniques during the last few years. It has the benefit of having an increased extraction rate and yield within a less period of time. UAE has many advantages over other methods due to reduced extraction time, less solvent consumption, low temperature, reduced equipment size, low energy requirements and high extraction yield (Chemat et al., 2008).

Natural antioxidants must be produced from affordable & effective sources to be used in the future to prevent diseases. On the other hand, the popularity of fruit drinks with added benefits is growing every day, a sign that more people are choosing natural remedies for their health problems. In the past few years, more study has been conducted on the Ultrasound Assisted Extraction (UAE) of polyphenols independently in developed nations, but Pakistan has only conducted a small number of tests using both antioxidants in a fruit drink with functional benefits. The research objectives were to carry out ultrasound assisted extraction of polyphenols from certain fruit peels (lemon & Mango) and using fruit waste to produce and assess beneficial fruit beverages using polyphenol extracts.

MATERIALS AND METHODS

Procurement of Raw Material

Lemon (*Citrus limon*), and Mango (*Mangifera indica* L.) peels for polyphenol's extraction were procured from the local market of Rawalpindi. The samples were taken to the Food and Nutrition Research Institute laboratory, National institute of Health (NIH), Islamabad. All the samples were washed and reduced in size to facilitate drying process. Apples & peaches were cleaned and juice extracted separately from each fruit using juice extractor (Anex AG-70).

Ultrasound Assisted Extraction of Polyphenols

Ultrasound Assisted Extraction of polyphenols from the lemon peel powder (LPP) and mango peel powder (MPP) were carried out using 70% (v/v) solution of ethanol according to an optimized method of (Safdar et al., 2017), taken in reagent bottles at 20:1 solvent/sample ratio for optimum extraction. They were placed in ultrasonic bath at 55 °C temperature and 35 kHz frequency for a period of 60 minutes. Extracts were subjected to solvent vacuum evaporation, filtration, and collected in amber glass bottles.

Determination Of Extraction Yield of Fruit Peel Powders

Extracts obtained from UAE of given treatments were analyzed for extraction yield (%) to estimate their economic value. Beakers used for drying peel extracts were weighed before and after adding the extracts.

Total Phenolic Contents of Fruit Peel Extracts

Total Phenolic Contents of phenolic extract of fruit peel extracts were determined by the method of Yamin et al. (2021) 0.05 g of each extract were dissolved in 5 mL ethanol, then 0.5 mL of this solution were added into a test tube containing 2.5 mL Folin-Ciocalteu reagent (10%) & 2.5 ml sodium carbonate (7.5%). Standard solutions of Gallic acid with different concentrations (12.5-400 µg/mL) were freshly prepared and added in test tubes. All test tubes were incubated at 25°C for 30 minutes, followed by recording absorbance at 765 nm using Agilent UV Spectrophotometer (Model, 8453).

Preparation of Functional Fruit Drink

Mix functional fruit drinks (Apple & Peach) were prepared & their storage stability was evaluated in 2 months monthly. To exclude any fibrous debris, pure apple & peach juice was strained through muslin cloth. The boiling water was mixed with sugar and then a mixture of 30 percent apple juice & 30 percent peach juice & then pasteurized at 80°C for 40 seconds. The pasteurized beverage will also then contain carboxymethyl cellulose, sodium benzoate, & citric acid.

The apple-peach beverage will also be then supplemented with 2% & 4% concentrations of 70% ethanolic polyphenol extracts from lemon & mango peels.

Table 2. Treatment plan for functional apple-peach drink fortification with polyphenols extract.

Treatments	Polyphenol extracts
T_0	0 % in 100mL
T_1	2% LPP in 100mL
T_2	4% LPP in 100mL
T_3	2% MPP in 100mL
T_4	4% MPP in 100mL

*T_0: Control treatment, T_1 2% Lemon peel polyphenol extract, T_2 4% Lemon peel polyphenol extract, T_3 2% Mango peel polyphenol extract, T_4 4% Mango peel polyphenol extract.

Physiochemical Analysis

Total soluble solids (TSS)

Total soluble solids were estimated in accordance with the AOAC, (2000) Method No. 942.15 technique using a refractometer in brix. Readings were adjusted at 20°C ± 0.5°C. After every reading, the prism of the refractometer was rinsed with distilled water.

Titratable acidity (TA)

The Titratable acidity was calculated as described in AOAC, (2000). One millilitre of the sample, nine millilitres of distilled water, along with a few drops of phenolphthalein indicator were added to determine the TA and the results were stated as acetic acid contents. To the end point (Pink color), titration was performed against 0.1 Normal solution of Sodium Hydroxide (NaOH).

pH

pH of the functional drink samples made from apple & peach were determined as described in AOAC, (2000) Method No. 981.12 using a digital pH meter. For calibration, buffer solutions with pH values of 4 & 7 were used.

Total phenolic contents of functional fruit drink

Total Phenolic Contents of the functional fruit drink for all treatments were determined from the standard curve of Gallic acid by the method of Yamin et al. (2021) as explained above for fruit peel extracts.

DPPH radical scavenging assay of functional fruit drink

Radical scavenging assay were performed for antioxidant activity estimation using DPPH (2,2-diphenyl-1-picrylhydrazyl) radical according to a modified method of Kanbarkar et al. (2022). Different concentrations (12.5-400 µg/mL) of each sample and blank (control) were added to 3 mL methanolic solution of DPPH (0.1 mM in 80% v/v methanol). After an incubation of 30 minutes in dark, absorbance was noted at 517 nm using Agilent UV Spectrophotometer (Model 8453).

Sensory evaluation of functional fruit drink

The functional apple-peach drink was scored by an experienced panel of experts utilizing a numerical scoring method of 9-point hedonic scale for sensory rating. The finished product was judged on its general acceptability, appearance, flavour, odor, taste, and texture, as followed by El-Saadony et al. (2020).

Statistical Analysis

Each experiment was conducted three times, and the results were statistically analyzed using the Two-way ANOVA method reported in Steel et al. (1997) using statistics tool version 8.1. The significance between mean differences of data was interpreted by the Least Significant Difference (LSD) Test.

RESULTS AND DISCUSSION

The research was carried out at two institutions, National Institute of Health (NIH) in Islamabad and IFNS Laboratory of PMAS-AAUR. The primary focus of the study was on utilizing ultrasound-assisted extraction to obtain polyphenols from two distinct fruits, namely lemon and mango. Subsequently, developing a functional drink by incorporating these extracts in varying proportions.

The investigation encompassed a comprehensive analysis of the drink, including assessments of its physio-chemical properties, total phenolic content, antioxidant capacity, and sensory characteristics.

Polyphenol Determination of Fruit Peels

The initial phase of the research involved the analysis of two different fruit peels, followed by the extraction of polyphenols from these peels. This phase encompassed a thorough preparation of the fruit peels, which is detailed as follows.

Preparation of Fruit Peel Powders

Table 3 shows the fresh fruit peels were weighed both on wet and dry bases. The results revealed that the lemon peel exhibited the highest weight loss, followed by the mango peel. This significant reduction in peel weight can be attributed to their elevated moisture content, which evaporated during the drying process, leading to substantial weight loss (Rahman et al., 2016).

Table 3. The weight of fruits peels before and after drying.

Treatments	Fresh weight (g)	Dry weight (g)	Total Wt. Loss (%)
Lemon Peel	750.30^{b}	60.60^{b}	91.96^{a}
Mango Peel	970.45^{a}	210.39^{a}	81.70^{b}

*Letters concerning to LSD comparison test.

Extraction Yield of Fruit Peel Powders

In the food industry, yield calculation is a crucial factor that significantly impacts the economic aspect of every sector. In this study, ultrasound-assisted extraction techniques were employed to extract polyphenols from different fruit peel powders. The results, as presented in Table 4, indicate that mango peel powder yielded the highest phenolic content at 34.51%, followed by lemon peel powder at 26.36%. These findings clearly demonstrate that mango peel powder contains the highest concentration of polyphenols, making it a preferred and stable choice for extracting and utilizing polyphenols in the development of functional drinks.

Table 4. Polyphenols extraction yield (%) of fruits peels.

Sample	Yield (%)
LPPE	26.36±0.46^{b}
MPPE	34.51±0.54^{a}

*LPPE (Lemon peel powder extract), MPPE (Mango peel powder extract), **All the values are mean of triplicates, ***Value ± is for standard deviation, ***Different alphabets show significant difference.

Total Phenolic Contents of Fruit Peel Extracts

Table 5 presents the data concerning the total phenol content (TPC) of fruit peels. The TPC was determined using a spectrophotometer and subsequently analyzed using appropriate statistical methods.

Table 5. Total phenol content of peels extract.

Sample	TPC (mg GAE/gm)
LPPE	37.8±0.50^{b}
MPPE	55.7±0.57^{a}

*LPPE (Lemon peel powder extract), MPPE (Mango powder peel extract), **All the values are mean of triplicates, ***Value ± is for standard deviation, ***Different alphabets show significant difference

Mango peel extract exhibited the highest TPC value, whereas the lowest TPC value was observed in lemon peel extract. These findings align with previous studies which showed that the peel from the mango powder had the greates TPC value of 35.5 mg GAE/g (Ajila & Rao, 2013; Vinha et al., 2014; Kaur et al., 2022). According to Khan et al. (2010), using the sonication process increases the yield of phenolic compounds. Conversely, the results showed that the peel from the lemon powder had the greatest 822 GAE/L total phenolic contents when extracted with fifty percent ethanol (Lucarini et al., 2022).

Anti-oxidant Activity of Fruit Extract

Antioxidants possess the ability to scavenge various radicals such as DPPH, $ABTS^{+}$, OH^{-}, superoxide, and other reactive oxygen species. Their activity in neutralizing these radicals is vital in providing protection against diseases associated with oxidative stress. Table 6 presents the values of antioxidant activity for fruit peels.

The results were promising, with mango peel extract showing the highest inhibition at approximately 88.06%, while lemon peel extract exhibited the lowest percentage of inhibition at 35.01%. These findings were consistent with previous research which demonstrate the highest value of inhibition of unripe mango and lemon peel was 114.27% and 32.53% (Ajila & Rao, 2013; Ali et al., 2023). The results demonstrated a significant difference in antioxidant activity among the fruit peel extracts, with mango peel extract exhibiting the highest fraction of antioxidant activity.

Table 6. DPPH radical Scavenging Activity of peel extract.

Name of Peel Extract	Inhibition %
LPPE	35.01±0.54^{b}
MPPE	88.06±0.57^{a}

*LPPE (Lemon peel powder extract), MPPE (Mango peel powder extract), **All the values are mean of triplicates, ***Value ± is for standard deviation, ***Different alphabets show significant difference.

Physico-Chemical Analysis of Functional Fruit Drink

Table 7 displays data for Total Soluble Solids, Titratable Acidity, and pH. The physicochemical characteristics of apple peach juices changed significantly ($p < 0.05$) as a result of the addition of polyphenols.

The incorporation of polyphenols from lemon and mango peels did not appear to have a major impact on pH, however after 15 days of storage, a considerable pH decrease was seen. Total Soluble Solids and Titratable Acidity rise over time as an outcome of polyphenol incorporation into fruit drinks.

The physicochemical characteristics of fruit drinks that have been chemically preserved have been strongly influenced by storage duration. Acid was used to convert sugars that are not reducing to reducing sugars during the acidic breakdown of polysaccharides, which is thought to be the cause of the decrease in acidity (Bhardwaj & Pandey, 2011). Data regarding a decrease of acidity and a rise in pH throughout storage are consistent with earlier findings of apple-carrot drink treated using ultrasound technique (Jingfei et al., 2012).

Table 7. Effect of treatments and storage on physicochemical profile of apple-peach drink.

Treatments	Storage Intervals (Days)	TSS	TA	pH
T_0	0	14.09^{N}	0.38^{O}	4.18^{A}
	15	14.75^{JKL}	0.46^{MNO}	4.16^{AB}
	30	15.25^{GH}	0.50^{LMN}	4.13^{ABC}
	45	16.59^{D}	0.54^{JKLM}	4.10^{BC}
	60	17.09^{BC}	0.57^{IJKL}	4.07^{C}
T_1	0	14.39^{M}	0.51^{KLM}	4.15^{AB}
	15	14.84^{JK}	0.58^{HIJKL}	3.92^{DC}
	30	15.95^{F}	0.62^{FGHIJ}	3.82^{FG}
	45	16.59^{D}	0.66^{EFGH}	3.78^{GH}
	60	17.29^{B}	0.69^{DEF}	3.70^{IJ}
T_2	0	14.65^{KL}	0.75^{BCD}	3.66^{J}
	15	15.10^{HI}	0.80^{ABC}	3.64^{J}
	30	16.15^{EF}	0.82^{AB}	3.31^{KL}
	45	16.98^{C}	0.85^{A}	3.25^{LM}
	60	17.50^{A}	0.87^{A}	3.16^{N}
T_3	0	14.59^{LM}	0.42^{NO}	4.17^{A}
	15	14.92^{IJ}	0.51^{KLM}	3.96^{D}
	30	16.09^{EF}	0.56^{IJKL}	3.86^{EF}
	45	16.69^{D}	0.64^{EFGHI}	3.81^{FG}
	60	17.36^{C}	0.67^{DEFG}	3.74^{HI}
T_4	0	14.79^{JKL}	0.59^{GHIJK}	3.67^{J}

	15	15.38^{G}	0.64^{EFGHI}	3.66^{J}
	30	16.22^{E}	0.68^{DEF}	3.33^{K}
	45	17.19^{BC}	0.72^{CDE}	3.27^{KL}
	60	17.59^{A}	0.79^{ABC}	3.20^{MN}

Total Phenolic Content (TPC) of Functional Fruit Drink

The juice samples, enriched with polyphenols extracted from various fruit peels, were analyzed for their TPC, and the results are presented in Table 8. The number of polyphenols in the apple-peach beverage supplemented with the polyphenolic extracts was measured using the Folin-Ciocalteu reagent.

The highest mean phenols content was observed in T_2 116.82 mg GAE/ml and T_4 116.07 mg GAE/ml, which had 4 grams of polyphenols of lemon and mango peels extract of polyphenols respectively. Whereas the least mean phenol observed in T_1 76.53 mg/ml which had a 2 gm of lemon peel extract. Whether the TPC of control sample means was 29.64mg/ml. The increase in polyphenol in added samples yielded favorable outcomes.

Table 8. Effect of treatment and storage on total phenolic content (mg GAE/ml) of apple-peach drink.

Treatments	TPC during the storage					
	0 Day	15^{th} Day	30^{th} Day	45^{th} Day	60^{th} Day	Treatment Means
T_0	60.3^{N}	36.02^{R}	26.07^{S}	15.6^{T}	10.2^{U}	29.64^{E}
T_1	102.76^{G}	90.97^{J}	83.7^{KL}	57.1^{O}	48.14^{Q}	76.53^{D}
T_2	150.84^{B}	128.97^{D}	104.1^{FG}	93.1^{I}	82.1^{L}	111.82^{B}
T_3	104.97^{F}	93.35^{I}	84.07^{K}	62.37^{M}	52.50^{P}	79.45^{C}
T_4	158.69^{A}	131.35^{C}	109.41^{E}	95.71^{H}	85.20^{K}	116.07^{A}
Storage Means	115.51^{A}	96.13^{B}	81.47^{C}	64.78^{D}	55.63^{E}	

Data showed that, relative to the control, the therapeutic apple-peach drink's TPC increased as polyphenolic extract levels increased. Throughout the storage period, TPC decreased in all treatments, regardless of whether apple peach drinks with added polyphenols were used. Yet, when compared to control samples, treatments with added polyphenols showed higher TPC even after storage. This finding aligns with similar results reported by Chiusano et al. (2015) made grape juice to ascertain the antioxidant capacity in relation to both temperature & time during the period of storage. It was shown that throughout the course of a 60-day period of storage at 20 & 4°C, phenolic activity reduced from 24 percent to 21.4 percent.

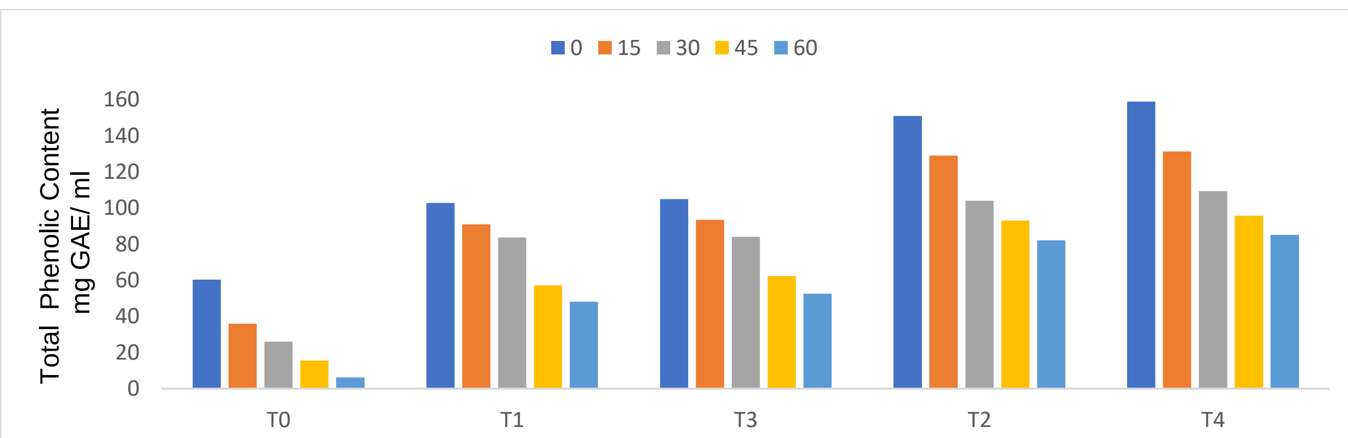

Figure 1. Effect of treatment and storage conditions on TPC (mg GAE/ml) of apple-peach drink supplemented with lemon and mango polyphenols.

Plant phenolics play a crucial role in reducing and preventing free radicals in the body, thereby reducing the risk of various diseases. The presence of polyphenol content in lemon and mango peels makes them valuable and cost-effective sources of polyphenol. The significantly maximum mean phenols (115.51 mg GAE/ml) were observed at 1st interval i.e., 0 days and minimum mean tpc (55.63 mg GAE/ml) was recorded at last interval i.e., 60 days.

DPPH Radical Scavenging Assay of Functional Fruit Drink

The juice with extracted polyphenols from fruits peels were tested for DPPH, the results are shown in Table 9. The treatments show the effect of different peels extract on Polyphenolic content of apple-peach juice. The highest inhibition was found in T_4 about 67.62 % with 4gm MPE though the lowest percentage 40.75% was found in 2gm LPE. Whereas the DPPH of control sample mean was 17.28%.

Table 9. Effect of treatment and storage on DPPH radical scavenging activity of apple-peach drink.

Treatments	DPPH during the storage					
	0 Day	15th Day	30th Day	45th Day	60th Day	Treatment Means
T_0	23.88^{R}	20.73^{S}	17.58^{T}	13.93^{U}	10.28^{V}	17.28^{E}
T_1	46.7^{J}	44.02^{K}	41.35^{M}	37.7^{O}	34^{Q}	40.75^{D}
T_2	51.2^{H}	47.6^{I}	44^{K}	40.35^{N}	36.7^{P}	43.97^{C}
T_3	57^{F}	53.9^{G}	50.7^{H}	46.7^{J}	42.7^{L}	50.12^{B}
T_4	74.22^{A}	71.07^{B}	67.92^{C}	64.27^{D}	60.62^{E}	67.62^{A}
Storage Means	50.60^{A}	47.46^{B}	44.31^{C}	40.51^{D}	36.86^{E}	

The results showed an increasing trend for mean value of DPPH by increasing concentration of peels extracts. Anti-oxidant activity is useful for defense against diseases related to oxidative stress. Anti-oxidants can fight free radicals which may play a role in heart disease, cancer and others.

The significant maximum mean inhibition (50.60%) was observed at 1st interval i.e., 0 days and minimum mean DPPH (36.86 mg GAE/ml) was recorded at last interval i.e., 60 days.

Sensory Evaluation of Functional Fruit Drink

Table 10 provides the results of an organoleptic examination of the apple-peach beverages enriched with polyphenolic extract for color, flavor, taste, & overall acceptability. Sensory characteristic scores for fruit drinks stored under refrigeration showed a declining tendency throughout the course of the storage period. After two months of refrigerator storage, the greatest declines in color (8.25-5.83), flavor (8.48-6.67), taste (8.40-6.53), mouth feel (7.75-6.05), & overall acceptance (7.94-5.97) were seen across the various treatments.

After 60 days of storage at fridge temperature, fruit drinks T_1 and T_3 are still palatable whereas T_0 and T_2 and T_4 are neither liked nor disliked. Since polyphenolic components typically have a bitter taste, the sensory panelist did not favor T_2 and T_4 as much. In kinnow nectar, a similar decreasing trend in sensorial attributes was observed during storage (Shubhra et al., 2014). Drinks made with green apple extract were said to have lost 10.73 percent of their color after 8 months of storage at 4 degrees Celsius (Rubio-Perez et al., 2014).

Table 10. Effect of treatment and storage on sensory attributes of apple-peach drink.

Treatments	Storage Intervals (Days)	Color	Flavor	Taste	Mouth Feel	Overall Acceptability
T_0	0	7.80^{F}	7.65^{G}	8.12^{DE}	7.60^{D}	7.79^{DE}
	15	7.02^{GH}	7.01^{I}	7.20^{I}	7.06^{H}	7.06^{G}
	30	6.01^{M}	6.06^{P}	6.15^{LM}	5.96^{R}	5.84^{Q}
	45	5.43^{P}	5.81^{Q}	5.92^{N}	5.66^{S}	5.55^{S}
	60	4.86^{Q}	5.57^{S}	5.48^{O}	5.37^{T}	5.27^{T}
T_1	0	8.08^{D}	7.93^{D}	8.45^{C}	7.83^{B}	8.07^{B}
	15	7.14^{G}	7.15^{H}	7.51^{FG}	7.33^{F}	7.40^{F}
	30	6.50^{J}	6.41^{L}	6.60^{J}	6.36^{N}	6.71^{J}
	45	6.16^{L}	6.29^{MN}	6.46^{JK}	6.02^{Q}	6.41^{LM}
	60	5.82^{N}	6.17^{O}	6.32^{KL}	5.68^{S}	6.11^{O}
T_2	0	7.75^{E}	7.76^{E}	7.98^{E}	7.55^{E}	7.74^{E}
	15	7.00^{H}	6.86^{J}	7.17^{I}	6.86^{J}	6.93^{H}
	30	5.83^{N}	6.03^{P}	6.28^{KL}	6.29^{O}	6.51^{K}
	45	5.58^{O}	5.63^{R}	6.15^{LM}	6.21^{P}	6.01^{P}
	60	5.33^{P}	5.23^{U}	6.07^{MN}	6.06^{Q}	5.72^{R}
T_3	0	8.99^{A}	8.65^{A}	8.85^{A}	8.10^{A}	8.29^{A}
	15	8.52^{B}	8.01^{C}	8.20^{D}	7.56^{DE}	8.06^{B}
	30	7.51^{F}	6.56^{K}	7.65^{HI}	6.96^{I}	6.84^{I}
	45	6.93^{HI}	6.31^{M}	7.52^{F}	6.66^{L}	6.65^{J}
	60	6.86^{I}	6.27^{N}	7.48^{FGH}	6.79^{K}	6.48^{KL}
T_4	0	8.97^{A}	8.48^{B}	8.65^{B}	7.67^{C}	7.83^{D}

15	8.38^{C}	7.72^{F}	8.12^{DE}	7.16^{G}	7.95^{C}
30	6.84^{I}	6.18^{O}	7.56^{F}	6.79^{K}	6.48^{KL}
45	6.35^{K}	5.65^{R}	7.47^{FGH}	6.57^{M}	6.39^{M}
60	6.27^{KL}	5.33^{T}	7.32^{GHI}	6.37^{N}	6.27^{N}

CONCLUSION

Comprehensive study concluded that mango peels exhibited favorable characteristics in terms of polyphenol levels, acidity, pH, and antioxidant activity. Lemon peels, while showing moderate results in these aspects, were not as prominent as mango peels. However, when using a concentration of 4mg, most samples from both mango and lemon peels resulted in a bitter taste, likely attributed to the higher levels of polyphenols. Additionally, the study indicated that the suboptimal taste of some samples might be due to improper handling during the experiment. This issue could be mitigated through improved handling techniques in future research. Overall, this study offers valuable insights into the potential of utilizing fruit peels to extract beneficial nutrients for the development of new products. By harnessing the knowledge gained from this research, it becomes possible to create high-quality food products, rich in essential nutrients, while keeping production costs low. This marks a significant step forward in promoting sustainable and cost-effective practices in the food industry.

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