Journal of Applied and Natural Science
16(2), 854 - 864 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Utilization of Kinnow peel for candy production: A study on quality attributes and storage stability

Harjinder Kaur
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara -114441 (Punjab), India
Gurpreet Singh*
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara -114441 (Punjab), India
Rupesh Kaushik
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara -114441 (Punjab), India
Ab Waheed Wani
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara -114441 (Punjab), India

*Corresponding author. E-mail: gurpreetraje@rediffmail.com

Article Info
https://doi.org/10.31018/jans.v16i2.5626
Received: April 03, 2024
Revised: June 03, 2024
Accepted: June 07, 2024

How to Cite
Kaur, H. *et. al.* (2024). Utilization of Kinnow peel for candy production: A study on quality attributes and storage stability. *Journal of Applied and Natural Science*, 16(2), 854 - 864. https://doi.org/10.31018/jans.v16i2.5626

Abstract
Kinnow fruit processing generates millions of tonnes of citrus waste yearly. This waste, predominantly of bitter-tasting peels, contributes significantly to environmental pollution when discarded. In this regard, the present study utilized kinnow peel waste for making candy, aiming to track down the straightforward, easy method of preparing the kinnow peel candies with extended shelf life. Additionally, it compared physical and chemical processes for removing bitterness from peels to create valuable food industry products, minimizing waste and enhancing fruit value, thus promoting food security with beneficial ingredients. In this laboratory investigation, the peel was treated with nine different treatments (T_1: Single boiling, T_2: Multiple boiling, T_3: Soaking in baking soda, T_4: Soaking in Vinegar, T_5: Soaking in Alum, T_6: Boiling in Salt solution, T_7: Boiling in bottle gourd juice, T_8: Boiling in cucumber juice, T_9: Control-No boiling). The resulting product was analysed for proximate, physicochemical, and organoleptic attributes at 15-day intervals for up to 45 days. The results showed an increase in crude fibre content (4.54-4.61 g/100g), total soluble solids (TSS) (75.14-75.40 ^{0}B), pH (2.92-3.07 %), reducing sugar (20.17-20.77 %), total solids (86.67-87.07 %), and total sugar (62.84-63.58 %). At the same time, the decrease was recorded in ash content (0.75-0.59 g/100g), moisture content (13.37-12.60 %), titratable acidity (0.43-0.38 %), ascorbic acid content (11.23-8.97mg/100g), tannins (55.90-55.27 mg/100g), antioxidant activity (44.50-40.71 %), total phenolic content (25.43-22.62 mg GAE 100 g−1), carotenoid content (1.39-1.32 mg/100g), and pectin content (1.50-1.34 mg/100g). The best treatment was T_2, which involved multiple boiling, cooking in 75 ^{0}B sugar syrup solution, and saturating with sugar syrup for 24 hours. It had desirable proximate, physicochemical and organoleptic properties and was stable for up to a minimum of 45 days for storage.

Keywords: Food security, Physicochemical properties, Processing, Sensory evaluation, Waste-utilization

INTRODUCTION

Citrus fruits have a universal appeal and are widely grown as tropical and subtropical fruit crops across the globe. Citrus fruits occupy 10% of India's area under fruit crops, ranking third after bananas and mango (Kaur and Singh, 2021). The *Citrus reticulata* Blanco, also known as the Kinnow mandarin, is a high-yielding hybrid of the King and Willow leaf mandarins (*Citrus nobilis X Citrus deliciosa*) and is a member of the Rutaceae family (Shorbagi *et al.,* 2022). Among these, kinnow mandarin leads in terms of yield, productivity, juice content, and fruit quality, making it an important fruit crop in Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh, Maharashtra, West Bengal, North Eastern Hill Region, and Rajasthan, with the maximum area under mandarin oranges in Andhra Pradesh followed by Maharashtra and Karnataka (Kumar *et al.,* 2022). In India, the total citrus production area was 1091 ('000 ha), and total production was

14150 ('000 MT) in 2021-22 (NHB, 2021-22).

Citrus fruits are nutrient-rich, containing essential vitamins (C, A, B), dietary fiber, riboflavin, minerals (potassium, manganese, copper, calcium, phosphorous, β-carotene), bio-active substances including carotenoids, enzymes, polyphenols, oils, etc. (Lu *et al.,* 2023). Citrus peels, the main by-product from citrus processing, are rich in pectin, cellulose, and hemicellulose, serving as abundant sources of bioactive phenolic compounds, notably bioflavonoids, with higher polyphenol content than the pulp (Teigiserova *et al.,* 2021; Singh *et al.,* 2021). As a precursor to vitamin A, beta-carotene in the peel helps combat diseases such as tumors, cardiac issues, and artery plaque. While cryptoxanthin contains anti-obesity, antioxidant, and anti-cancer properties, lutein is associated with anti-inflammatory properties, enhanced eye and heart health, the protection of age-related macular degeneration, and a decreased risk of cervical cancer (Arias *et al.,* 2022).

The globally cultivated kinnow fruit, producing over 88 million tonnes, has various parts serving different purposes. Its juicy placental hairs are consumed, while peels are used in baked goods, marmalades, and candied peels. Additionally, similar to other vegetables and fruits like carrot, apple, guava, mango, and orange rind (peel), kinnow peel is employed in candy making. Due to the rising production and processing of fruits and vegetables, the use of waste from these industries has become one of the world's most challenging issues. Despite its substantial utilization, kinnow fruit processing generates around 40 million tonnes of citrus waste annually, constituting 50% of the original fruit mass in juice processing industries (Kaur and Singh, 2021). Additionally, 30–40% of kinnow peel becomes a significant by-product, causing atmospheric pollution if inadequately treated (Wedamulla *et al.,* 2022; Yaqoob *et al.,* 2020a, 2020b; Panwar *et al.,* 2021). The large volume of kinnow peel by-product requires effective treatment and disposal due to susceptibility to microbial spoilage, limiting further exploitation. Candying is one of the oldest food preservation methods and antedates refined sugar manufacture (Zia *et al.,* 2021). Therefore, try to develop products from waste, such as orange peel into candy, make part of the fruit processing industries, and make a contribution to reducing hazardous environmental effects rather than discarding food items of lower quality (Sharma *et al.,* 2021).

Nagar and Rastogi (2022) studied the preparation of fruit peel candies and found that candies prepared with C3 (10 g orange peel powder +10 g lemon peel powder + 100 g sugar) was most acceptable in terms of sensory and physicochemical ratings. Kumar *et al.* (2022) studied the preparation of orange peel candies and found that candies prepared with T4 (40% sugar + only albedo) earned the highest results in the organoleptic and biochemical aspects during 90 days of storage period. Mohanta *et al.* (2021) prepared five different samples of orange (*Citrus sinensis*) peel with different combinations of sugar, honey and peel. The formulated orange peel candies are regarded as acceptable, and all the prepared samples were made to be "moderately good." They can be used industrially to create a profitable product. Studies by (Kumar *et al.,* 2022; Mohanta *et al.,* 2021; Nagar and Rastogi, 2022) have explored the preparation of citrus peel-based value-added products, with orange peel candy samples being considered acceptable for industrial purposes and boost the processing industry's profits and pay growers a reasonable price. Henceforth, the present tracked down the basic (easy), straightforward method of preparing the kinnow peel candies with a maximum shelf life and compared the physical and chemical methods to remove bitterness from the peel for building valuable products in the food industry by reducing waste.

MATERIALS AND METHODS

This study was conducted at the Department of Horticulture in the School of Agriculture at Lovely Professional University in Phagwara, Punjab (India). This research study involved using fresh and mature kinnow fruits harvested from a farm in Hoshiarpur, Punjab. Before use, fruits were examined to ensure they were free from any blemishes, bruising, damage, or infestation. In addition, various food additives such as salt, alum, vinegar, baking soda, cucumber, and bottle gourd were procured from the local market.

Damage-free peels were manually separated and graded according to the desired size to produce kinnow rind candies. After that, the peels were rinsed in running water to remove the outer dirt and dust. The white part of the internal side of the peels was physically removed and the remaining peel was uniformly cut into 4-5 cm lengths and 0.5-1 cm widths. Nine different treatments were then applied to the cut peels, i.e. T_1: Single boiling, T_2: Multiple boiling, T_3: Soaking in baking soda, T_4: Soaking in Vinegar, T_5: Soaking in Alum, T_6: Boiling in Salt solution, T_7: Boiling in bottle gourd juice, T_8: Boiling in cucumber juice, T_9: Control (No boiling). After the treatments, the kinnow peels were cooked in 75 ^{0}B syrup (sugar) solution for 5 to 8 minutes, steeped in the syrup (sugar) for 24 hours, and dried for 6 hours at 70° C using a tray dryer. The dried candies were then packed in plastic containers and stored at ambient temperature (15 ^{0}C to 25 ^{0}C) for 45 days for further analysis. The flow chart of the preparation of candies is shown in Fig. 1.

The samples' physicochemical characteristics were ascertained using AOAC (2005) methodology. The pH was determined using a digital pH meter. TSS was determined by using the digital refractometer (Atago N1,

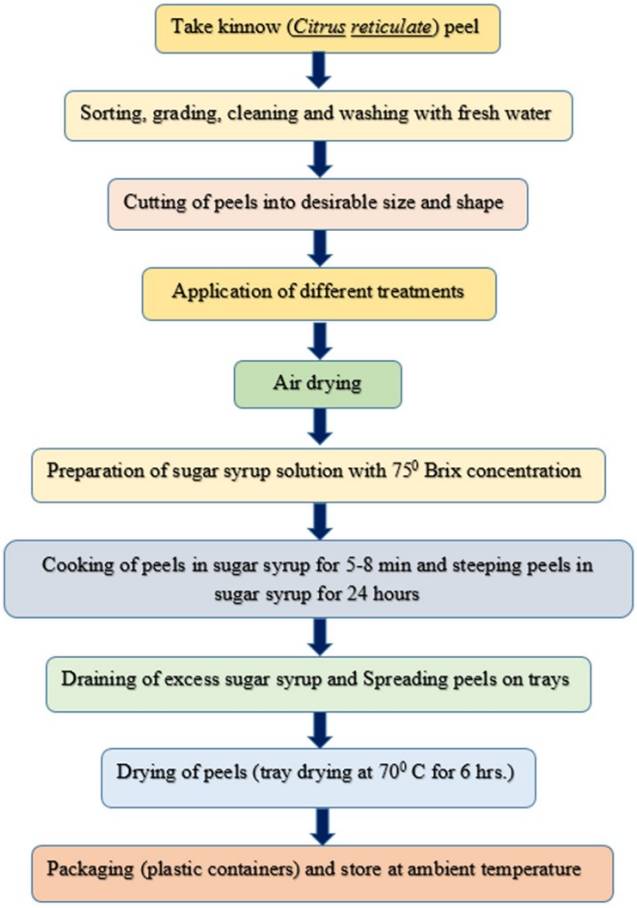

Fig. 1. *Flow chart for preparation of candies*

Tokyo, Japan), whereas sugars (total sugar and reducing sugar) were determined by Lane and Eyon's methodology given using AOAC (2005). Total phenolic content (TPC) was calculated using the Folin-Ciocalteau technique with a UV-VIS Lambda 25 spectrophotometer (Costea *et al.,* 2022). The antioxidant activity of jam samples was analysed using the DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging method using UV-Vis spectrophotometer (UVD-3200, Labomed, Inc., Culver City, USA) (Zhou and Huang, 2023). A panel of 10 trained judges used a 9-point hedonic scale to conduct sensory analysis while using AOAC (2005) methodology. Triplicate analyses were conducted, and data was recorded for each parameter at 15-day intervals, starting from day 0 up to 45 days. The OPSTAT statistical analysis program was used to conduct the one-way analysis of variance (ANOVA) procedures on the data in a completely randomized design with three replications.

RESULTS AND DISCUSSION

Effect of storage on proximate, physicochemical and sensory attributes of kinnow peel candy

Ash content

During storage, the ash content (g/100g) of kinnow peel candy showed a significant decrease. The mean score for ash content decreased from 0.68 to 0.51 g/100g (Table 1). After 45 days of storage, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest value of ash content (0.59 g/100g), while T_9 (Control with no boiling) showed the lowest value (0.44 g/100g). The ash content of kinnow peel candies was measured to determine the quantity and kind of minerals present in the product. The form and quantity of minerals aid in slowing the growth of microbes and are crucial for analyzing the physio-chemical properties of food. The microbes using the minerals for growth could be the cause of this fall in ash content. These results are in line with the results of Nagar and Rastogi (2022), who also found a decreasing trend in ash content in fruit peel candies during the storage of 30 days and similarly, the decline in ash content was also observed by Aggarwal *et al.* (2022) in kinnow bar during the storage of 3 months.

Crude fibre content

The crude fibre content (g/100g) of kinnow peel candy significantly increased throughout storage, with a significance level of 5%. Crude fibre content increased on average from 3.66 to 4.58 g/100g (Table 1). T_2 (Multiple boiling three times for 8 to 10 min) showed the highest value of crude fibre content (4.61 g/100g), while T_9 Control (No boiling) showed the lowest value of crude fibre content (3.69 g/100g) after 45 days of storage. The conversion of soluble and insoluble dietary fibres, which make up the bulk of food, is responsible for the increase in crude fibre content of candies. These results are in alignment with the findings of Nagar and Rastogi (2022), Aggarwal *et al.* (2022) and Bansode *et al.* (2021), who also observed an increment in crude fibre content in fruit peel candies during the storage of 30 days, in kinnow bar during the storage of 3 months and in the ginger candy over 90 days storage, respectively.

Moisture content (%)

At a significance level of 5%, the various methods of preparing kinnow peel candy were found to have a significant effect on moisture content (%) over different intervals. The mean moisture content decreased from 17.16% to 13.00%. After 45 days of storage, T_9 Control (No boiling) exhibited the highest moisture content value (16.80%), whereas T_2 (Multiple boiling three times for 8 to 10 min) showed the lowest moisture content value (12.60%) (Table 1). Possible causes for the drop in moisture content include osmotic pressure caused by the sugar solution, which causes water to exit the cells of the peel due to the pressure of sugar molecules on the cell wall, reducing sugar concentration and moisture content. Furthermore, the decrease in moisture content could also be attributed to evaporation from the samples during storage. These findings are consistent with

those Bansode *et al.* (2021), who studied the effect of storage on the chemical and sensory attributes of ginger candy and found a decline in the moisture content over 90 days of storage. Another study by Shruthi and Bahadur (2020) also found a drop in the moisture content of karna khatta (*Citrus karna*) peel candy during 90 days of storage. Similarly, the decline in moisture content of strawberry and red beetroot jelly candies was seen during storage by Ali *et al.* (2021).

Titratable acidity (%)

The titratable acidity (%) of kinnow peel candy significantly decreased over the course of storage, with a significance level of 5%. Titratable acidity reduced on average from 0.60 % to 0.40 % (Table 1). T_2 (Multiple boiling three times for 8 to 10 min) showed the lowest value of titrable acidity (0.38%), while T_9 Control (No boiling) showed the highest value of titrable acidity (0.56%) after 45 days of storage. The drop in titrable acidity could be attributed to the leaching of acids in sugar solution over time or the relationship that develops over time between the acid and peel component, which may explain the decrease in the acidity of kinnow peel candy. These outcomes are in conformity with the findings of Khandare and Syed (2019), who also reported a decrease in titratable acidity of Indian gooseberry (*Emblica officinalis*) candy during the storage. Varsha *et al.* (2021) also observed a decreasing trend in titrable acidity of candy from orange (*Citrus sinensis*) peel stored at ambient temperature for about 120 days.

pH (%)

During the storage period of kinnow peel candy, a significant increase in pH (%) was observed at a significance level of 5%. The mean pH increased from 2.23 % to 2.99 % (Table 1). After 45 days of storage, T_2 (Multiple boiling three times for 8 to 10 min) showed the highest pH value (3.07), while T_9 Control (No boiling) showed the lowest pH value (2.27). The increase in pH could be attributed to a decrease in candy acidity during storage. This result is in line with the outcomes of Kaur and Singh (2021), who reported a similar drop in the levels of pH during storage in kinnow (*Citrus nobilis* X *Citrus deliciosa*) peel candy and Kumar *et al.* (2022) also found a decrease in pH content of orange (*Citrus reticulata* L.) peel candy during the storage of 90 days.

Ascorbic acid (mg/100g)

The study found that vitamin C (mg/100g) exists in two forms, ascorbic acid and dehydroascorbic acid, which are both volatile and unstable. The Mean score for ascorbic acid decreased significantly from 10.10 mg/100g to 5.26 mg/100g (Table 2), with T_1 Single boiling (15 min) showing the highest value of ascorbic acid (8.97 mg/100gm) and T_9 Control (No boiling) showing the lowest content of ascorbic acid (3.56 mg/100g) after 45 days of storage of candy. The ascorbic acid content may have decreased as a result of processing-related heat degradation and storage-related oxidation. This finding is consistent with the results reported by Khandare and Syed (2019), who observed a decrease in the ascorbic acid content of Indian gooseberry (*Emblica officinalis*) candy during storage of 120 days. Similarly, Kumar *et al.* (2022) revealed that the ascorbic acid values tend to decline during the storage of 90 days in orange (*Citrus reticulata* L.) peel candy. Another investigation by Ali *et al.* (2021) also found a decreasing trend in the ascorbic acid content of functional strawberry and red beetroot jelly candies.

Total solids content (%)

During storage, the total solids content (%) of kinnow peel candy showed a significant increase. The mean score for total solids increased from 82.98 % to 86.87 %, indicating a concentration of the sugar solution during storage (Table 2). After 45 days of storage, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest value of total solids content (87.07%), while T_9 (Control with no boiling) showed the lowest value (83.50%). This rise in the total solids content may be caused by the product's natural dehydration during storage, resulting in a sugar solution concentration. Shruthi and Bahadur (2020) found an increase in the total solids content of karna khatta (*Citrus karna*) peel candy during the storage of 90 days. These results are in line with the findings reported by Muzzaffar *et al.* (2016), who also discovered an increase in the levels of total solids content in pumpkin candy, stored about 3 months. Similarly, Nagar and Rastogi, (2022) studied the preparation and nutritional quality evaluation of fruit peel candies and observed increment in total solids content during the storage of 50 days.

Total soluble solids (TSS) (%) (^{0} B)

The results indicate a significant increase in the Mean score for total soluble solids (TSS) from 70.92 % to 75.27 % (Table 2). T_2 (Multiple boiling three times for 8 to 10 min) showed the highest value of total soluble solids content (75.40 %), while T_9 Control (No boiling) exhibited the lowest value (72.90 %) after 45 days of storage. The rise in total soluble solids content may be attributed to the hydrolysis mechanism that converts polysaccharides into sugars. In addition, the decrease in the moisture content of the samples during storage may have contributed to the rise in total soluble solids (TSS). During storage, an increase in total soluble solid content was reported in ginger candy by Bansode *et al.* (2021). However, Urooj (2021) also showed a rise in the total soluble solids content of wood apple (*Limonia acidissim*) and passion fruit (*Passiflora edulis*) candies during 90 days storage. The increase in total soluble solids was also shown by Kumar *et al.* (2022) in orange

Table 1. Effect of various methods of preparing kinnow peel candy on ash content, crude fibre content, moisture content, titratable acidity and pH at different days of intervals

Treatments	Storage period (days)														
	Ash content (g/100g)			Crude fibre (g/100g)			Moisture content (%)			Titratable acidity (%)			pH (%)		
	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean
T_1: Single boiling	0.73^{a}	0.57^{a}	0.66	4.26^{b}	4.33^{b}	4.30	13.60^{b}	12.83^{b}	13.23	0.45^{a}	0.39^{a}	0.42	2.84^{ab}	2.91^{ab}	2.87
T_2: Multiple boiling	0.75^{a}	0.59^{a}	0.68	4.54^{a}	4.61^{a}	4.58	13.37^{b}	12.60^{b}	13.00	0.43^{a}	0.38^{a}	0.40	2.92^{a}	3.07^{a}	2.99
T_3: Soaking in baking soda	0.60^{a}	0.49^{a}	0.55	3.68^{e}	3.75^{de}	3.72	16.87^{a}	16.23^{a}	16.53	0.62^{a}	0.56^{a}	0.59	2.55^{abc}	2.67^{abc}	2.61
T_4: Soaking in Vinegar	0.57^{a}	0.47^{a}	0.53	3.74^{de}	3.81^{cde}	3.78	14.47^{b}	13.83^{b}	14.13	0.56^{a}	0.49^{a}	0.52	2.78^{ab}	2.86^{ab}	2.82
T_5: Soaking in Alum	0.67^{a}	0.52^{a}	0.60	3.91^{cd}	3.98^{cd}	3.95	14.00^{b}	13.33^{b}	13.67	0.63^{a}	0.55^{a}	0.59	2.79^{ab}	2.85^{ab}	2.82
T_6: Boiling in Salt solution	0.71^{a}	0.54^{a}	0.63	4.00^{c}	4.07^{c}	4.04	16.53^{a}	15.77^{a}	16.13	0.45^{a}	0.39^{a}	0.42	2.74^{abc}	2.83^{ab}	2.78
T_7: Boiling in bottle gourd juice	0.65^{a}	0.48^{a}	0.57	3.63^{e}	3.70^{e}	3.67	16.53^{a}	15.83^{a}	16.17	0.63^{a}	0.55^{a}	0.59	2.31^{bc}	2.41^{c}	2.36
T_8: Boiling in cucumber juice	0.62^{a}	0.46^{a}	0.55	3.71^{de}	3.78^{de}	3.75	17.00^{a}	16.30^{a}	16.65	0.63^{a}	0.54^{a}	0.58	2.42^{abc}	2.49^{bc}	2.45
T_9: Control (No boiling)	0.56^{a}	0.44^{a}	0.51	3.62^{e}	3.69^{e}	3.66	17.53^{a}	16.80^{a}	17.16	0.64^{a}	0.56^{a}	0.60	2.19^{c}	2.27^{c}	2.23
Mean	0.51	0.50	0.50	3.91	3.97	3.94	15.54	14.84	15.18	0.56	0.49	0.52	2.61	2.70	2.66

Mean values in rows with different letters are significantly different ($p < 0.05$)

Table 2. Effect of various methods of preparing kinnow peel candy on ascorbic acid, total solids, total soluble solids, pectin and tannins at different days of intervals

Treatments	Storage period (days)														
	Ascorbic acid (mg/100g)			Total solids (%)			TSS (%) (^{0} Brix)			Pectin (% Cal pectate)			Tannins (mg/100g)		
	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean
T_1: Single boiling	11.23^{a}	8.97^{a}	10.10	86.37^{a}	86.74^{a}	86.55	74.67^{b}	75.03^{ab}	74.85	1.66^{a}	1.49^{a}	1.57	74.45^{a}	72.48^{b}	73.47
T_2: Multiple boiling	11.13^{a}	8.87^{a}	10.00	86.67^{a}	87.07^{a}	86.87	75.14^{a}	75.40^{a}	75.27	1.50^{a}	1.34^{a}	1.42	55.90^{g}	55.27^{g}	55.59
T_3: Soaking in baking soda	7.57^{d}	3.76^{b}	5.66	83.60^{b}	84.10^{b}	83.85	71.99^{f}	72.41^{c}	72.20	1.43^{a}	1.27^{a}	1.35	67.83^{d}	67.23^{d}	67.53
T_4: Soaking in Vinegar	8.22^{c}	5.77^{a}	6.99	85.67^{a}	86.17^{a}	85.92	73.71^{d}	74.03^{b}	73.87	1.63^{a}	1.48^{a}	1.55	53.19^{h}	52.5^{h}	52.85
T_5: Soaking in Alum	10.48^{b}	7.45^{b}	8.96	86.00^{a}	86.47^{a}	86.23	74.11^{c}	74.40^{ab}	74.25	1.61^{a}	1.32^{a}	1.46	73.19^{b}	73.89^{a}	73.54
T_6: Boiling in Salt solution	8.02^{c}	5.91^{a}	6.96	83.37^{b}	83.77^{b}	83.57	72.57^{e}	73.60^{e}	73.08	1.41^{a}	1.24^{a}	1.32	64.18^{e}	63.56^{e}	63.87
T_7: Boiling in bottle gourd juice	7.12^{ef}	3.78^{b}	5.45	83.10^{b}	83.63^{b}	83.36	69.73^{h}	70.40^{de}	70.06	1.55^{a}	1.34^{a}	1.44	59.31^{f}	58.53^{f}	58.92
T_8: Boiling in cucumber juice	7.42^{de}	3.86^{b}	5.64	83.27^{b}	83.80^{b}	83.53	70.48^{g}	71.13^{d}	70.80	1.51^{a}	1.25^{a}	1.38	70.53^{c}	69.23^{c}	69.88
T_9: Control (No boiling)	6.97^{f}	3.56^{b}	5.26	82.47^{b}	83.50^{b}	82.98	68.95^{i}	72.90^{c}	70.92	1.38^{a}	1.21^{a}	1.29	53.04^{h}	52.39^{h}	52.72
Mean	8.66	5.77	7.22	84.50	85.02	84.76	72.37	73.25	72.81	1.52	1.32	1.42	63.51	62.79	63.15

Mean values in rows with different letters are significantly different ($p < 0.05$)

(*Citrus reticulata* L.) peel candy during the storage of 90 days.

Pectin (% Cal pectate)

At a 5% significance level, it was discovered that the pectin concentration (% Cal pectate) of kinnow peel candy significantly decreased after storage. The mean pectin score decreased from 1.42 to 1.29 % Cal pectate (Table 2). T_1 Single boiling (15 min) showed the highest pectin content (1.49 % Cal pectate), while T_9 Control (No boiling) showed the lowest pectin content (1.21 % Cal pectate) after 45 days of storage. The drop in pectin content during storage could be attributed to pectin breakdown into pectic acids, as suggested by Muzzaffar *et al.* (2016) in pumpkin candy. Similar decreases in pectin content have been observed in kinnow (*Citrus nobilis* X *Citrus deliciosa*) peel candy by Kaur and Singh (2021) for storage.

Tannins content (mg/100g)

The tannins content (mg/100g) of kinnow peel candy significantly decreased over the course of storage, with a significance level of 5%. Tannins content reduced on average from 73.47 to 52.72 mg/100g (Table 2). The maximum tannin content at zero-day was found in T_1 Single boiling (15 min) (74.45 mg/100gm), while the minimum showed by T_9 Control (No boiling) (53.04 mg/100gm). After 45 days of storage of candy, T_1 Single boiling (15 min) showed the maximum value of tannins content (72.48 mg/100g) and T_9 Control (No boiling) showed the minimum value of tannins content (52.39 mg/100g) at the end of storage. Because tannins are highly volatile and quickly oxidised to create high-molecular weight brown compounds, tannins in kinnow peel candy reduced. This could be owing to the fact that they condense into brown pigments. These results align with the earlier discoveries made by Khandare and Syed (2019), who showed a decline in the tannin content of Indian gooseberry (*Emblica officinalis*) candy during storage of 120 days.

Total sugars (%)

The outcomes showed a significant rise in the mean score for total sugars (%) from 44.27 % to 63.21 % (Table 3). At the end of the 45-day storage period, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the maximum value of total sugar content (63.58 %), while T_9 Control (No boiling) showed the minimum value of total sugar content (44.71 %). The concentration of sugars caused by the loss of moisture content can be linked to the steady and large increase in total sugars in kinnow peel candy. Urooj, (2021) revealed that the total sugars of wood apple (*Limonia acidissim*) and passion fruit (*Passiflora edulis*) candies were found to increase with the increase in storage (90 days) time. Shruthi and Bahadur (2020) also showed an increase in the total sugar content of Karna Khatta (*Citrus karna*) during 90 days of storage. Similarly, Ali *et al*. (2021) also found an increment in total sugars in functional strawberry and red beetroot jelly candies during storage.

Reducing sugars (%)

During the storage period of Kinnow peel candy, at significance level of 5%, a significant rise in the concentration of reducing sugars (%) was seen. The mean value for reducing sugars increased from 17.15 % to 20.62 % (Table 3). T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest content of reducing sugars (20.77%) after 45 days of storage, while T_9 Control (No boiling) showed the lowest value of reducing sugars (17.63%) at the end of storage. The hydrolysis of non-reducing carbohydrates into reducing sugars may cause this increase. The investigation by Kaur and Singh (2021) also noticed a similar moderate increase in reducing sugar levels during storage in kinnow (*Citrus nobilis* X *Citrus deliciosa*) peel candy. Comparably, during the storage of 90 days, an increasing trend in reducing sugar content was seen in orange (*Citrus reticulata* L.) peel candy by Kumar *et al.* (2022).

Total phenolic content (TPC) (mg GAE 100 g−1)

The outcomes showed a significant decrease in the mean score for total phenolic content (TPC) (mg GAE 100 g−1) from 24.03 to 13.96 mg GAE 100 g −1 (Table 3). At the end of the 45-day storage period, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the maximum value of total phenolic content (22.62 mg GAE 100 g−1), while T_9 Control (No boiling) showed the minimum value of total phenolic content (12.43 mg GAE 100 g−1). This could mainly result from oxidation, degradation of phenolic compounds, and polymerization of phenolic compounds with proteins. This decrease could also be due to cell structure disruption during processing, as Halim *et al.* (2022) demonstrated in roselle (*Hibiscus sabdariffa* L.) calyx jelly candy. Ali *et al.* (2021) also revealed that the total phenolic content tend to decrease with the increase in storage duration of strawberry and red beetroot jelly candies. Rafiq *et al.* (2019) also showed a decline in total phenolic content in different drying techniques of kinnow peel.

Antioxidant activity (%)

During the storage period of kinnow peel candy, at the significance level of 5%, a significant decrease in antioxidant activity (%) was seen. The mean value for antioxidant activity decreased from 42.61 to 31.39 % (Table 3). T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest antioxidant activity (40.71 %) after 45 days of storage, while T_9 Control (No boiling) showed the lowest value of antioxidant activity (29.49 %) at the end of storage. The elevated temperatures or

thermal treatments applied during processing, which alter polyphenols' solubility or chemical reactivity, may cause a drop in kinnow peel candy's antioxidant activity. The antioxidant components, however, will probably go through a chemical change. These findings are in accordance with the previous studies, such as Rezagholizade-Shirvan *et al*. (2023) and Suman *et al.* (2021) in watermelon rind candy and ginger-supplemented jelly candies which reported a drop in antioxidant activity during storage, respectively. However, Muzzaffar *et al.* (2016) also showed a higher loss in antioxidant activity of pumpkin candy during storage.

Carotenoid content (mg/100g)

At a significance level of 5%, the various methods of preparing kinnow peel candy were found to have a significant effect on carotenoid content (mg/100g) over different intervals. The mean carotenoid content decreased from 1.36 mg/100h to 1.13 mg/100g. After 45 days of storage, T_9 Control (No boiling) exhibited the carotenoid content value (1.32 mg/100g), whereas T_2 (Multiple boiling three times for 8 to 10 min) showed the lowest carotenoid content value (1.09 mg/100g) (Table 3). The high susceptibility of carotenoids to auto-oxidative destruction during food processing and storage may cause a decline in carotene content in candies. Additionally, the degree of carotenoid reduction varies according to the raw material type, processing temperature, and heat treatment method. These outcomes are per the results of Aggarwal *et al.* (2022) and Hien and Nguyet (2021), who revealed that kinnow bar and chocolate candy fillings' carotenoid content decreased as storage time increased, respectively.

Colour

The colour of candy is an important aspect of consumer acceptability, and the present study studied the impact of storage and processing methods on the colour of candy. The results revealed a significant drop in colour during the storage period, which was statistically significant at a 5% significance level. The average colour score dropped from 8.01 to 6.46 (Fig. 2). Among the different processing methods, T_2 (Multiple boiling three times for 8 to 10 min) showed the highest colour value (7.90) after 45 days of storage, whereas T_9 Control (No boiling) showed the lowest colour value (6.20). The decrease in colour score could be attributed to non-enzymatic browning due to the Maillard reaction between the candy's reducing sugars and amino acids. The high temperatures used during processing and subsequent storage could accelerate this reaction, resulting in a significant drop in the colour of the candy. These findings are consistent with the investigation of Urooj (2021), who observed a decline in colour values of wood apple (*Limonia acidissim*) and passion fruit (*Passiflora edulis*) candies during 90 days storage and

Table 3. Effect of various method of preparing kinnow peel candy on total sugars, reducing sugar, total phenolic content, antioxidant activity and carotenoid content at different days of intervals

Treatments	Storage period (days)													
	Total sugars (%)			Reducing sugar (%)			Total phenolic content (mg GAE 100 g−1)			Antioxidant activity (%)			Carotenoid content (mg/100g)		
	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean	0 day	45th day	Mean
T_1: Single boiling	58.73^{b}	60.11^{b}	59.42	19.87^{a}	20.65^{a}	20.29	23.88^{b}	20.95^{b}	22.42	43.63^{b}	39.84^{b}	41.74	1.35^{a}	1.28^{a}	1.32
T_2: Multiple boiling	62.84^{a}	63.58^{a}	63.21	20.17^{a}	20.77^{a}	20.62	25.43^{a}	22.62^{a}	24.03	44.50^{a}	40.71^{a}	42.61	1.39^{a}	1.32^{a}	1.36
T_3: Soaking in baking soda	51.80^{d}	52.39^{d}	52.09	17.59^{cd}	18.28^{bc}	17.97	16.91^{e}	14.33^{e}	15.63	34.61^{h}	30.82^{h}	32.72	1.22^{a}	1.15^{a}	1.19
T_4: Soaking in Vinegar	53.25^{c}	53.75^{c}	53.50	18.78^{abc}	19.60^{ab}	19.24	17.02^{e}	14.66^{e}	15.85	35.32^{g}	31.53^{g}	33.43	1.19^{a}	1.12^{a}	1.16
T_5: Soaking in Alum	53.74^{c}	54.07^{c}	53.90	19.67^{ab}	20.55^{a}	20.14	20.69^{c}	16.26^{d}	18.48	35.92^{f}	32.13^{f}	34.03	1.30^{a}	1.23^{a}	1.27
T_6: Boiling in Salt solution	52.98^{cd}	53.66^{c}	53.32	16.66^{d}	18.20^{bc}	17.04	21.02^{c}	16.68^{c}	18.86	41.30^{c}	37.51^{c}	39.41	1.33^{a}	1.26^{a}	1.30
T_7: Boiling in bottle gourd juice	49.95^{e}	50.51^{e}	50.23	16.79^{d}	18.14^{bc}	17.24	18.82^{d}	16.12^{d}	17.48	39.63^{d}	35.84^{d}	37.74	1.27^{a}	1.20^{a}	1.24
T_8: Boiling in cucumber juice	51.72^{d}	52.30^{d}	52.01	18.14^{bcd}	18.98^{bc}	18.53	18.58^{d}	14.52^{e}	16.56	38.52^{e}	34.73^{e}	36.63	1.25^{a}	1.18^{a}	1.22
T_9: Control (No boiling)	43.85^{f}	44.71^{f}	44.27	16.49^{d}	17.63^{c}	17.15	15.49^{f}	12.42^{f}	13.96	33.28^{i}	29.49^{i}	31.39	1.16^{a}	1.09^{a}	1.13
Mean	53.20	53.89	53.55	18.24	19.01	18.68	19.76	16.51	18.14	38.53	34.74	36.63	1.28	1.21	1.25

Mean values in rows with different letters are significantly different ($p < 0.05$)

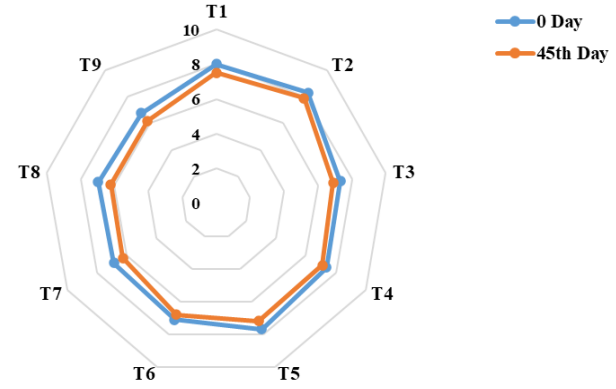

Fig. 2. *Effect of various method of preparing kinnow peel candy on colour at different day intervals*

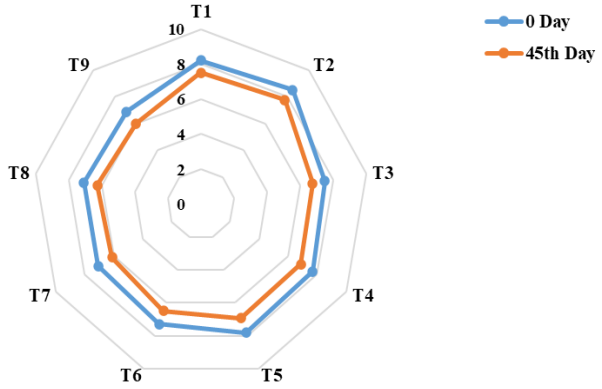

Fig. 4. *Effect of various method of preparing kinnow peel candy on texture at different day*

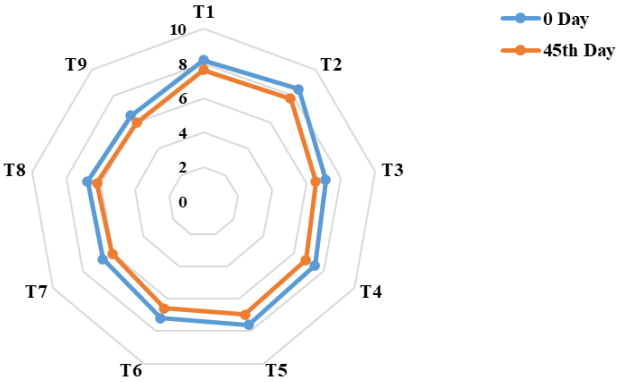

Fig. 3. *Effect of various method of preparing kinnow peel candy on flavor at different day intervals*

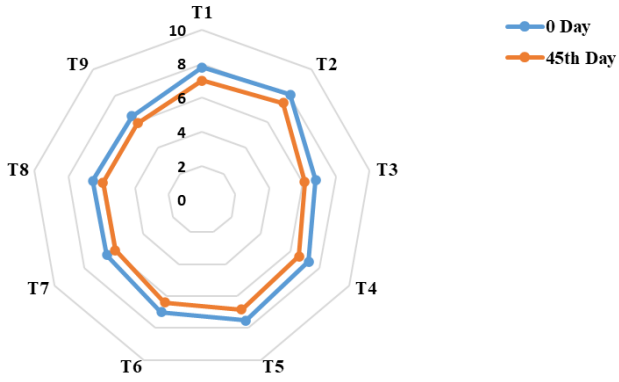

Fig. 5. *Effect of various method of preparing kinnow peel candy on overall acceptability at different day intervals*

Shruthi and Bahadur (2020) also seen loss in colour values of karna khatta (*Citrus karna*) peel candies during storage of 90 days.

Texture

At a 5% significance level, the candy texture decreased significantly during storage. As shown in Fig. 3, the mean score for texture dropped from 8.13 to 6.45. Among the different treatments, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest texture value (7.77) after 45 days of storage, while the control group, T_9 (No boiling), showed the lowest texture score (6.00). The Kinnow peel candy's loss of moisture content after storage could be the cause of the texture score's decline. These findings are in accordance with the results reported by Urooj (2021), who observed a drop in the texture values of wood apple (*Limonia acidissim*) and passion fruit (*Passiflora edulis*) candies stored for 90 days. Similarily, a decline was seen in the texture values of ginger candy during the storage of 90 days (Bansode *et al.*, 2021). A decline in texture values of Karna Khatta (*Citrus karna*) peel candies was seen over 90 days when stored at room temperature (Shruthi and Bahadur, 2020). The texture of the candy is an important quality attribute that affects the overall sensory experience of consumers. Therefore, it is essential to optimize the processing conditions and storage parameters to maintain the desired texture of the candy during shelf life.

Flavour

At a 5% significance level, a significant decrease in the flavour of kinnow peel candy was observed during storage. The mean score for flavour dropped from 8.25 to 6.23 (Fig. 4). After 45 days of storage, T_2 (Multiple boiling three times for 8 to 10 min) exhibited the highest flavour score (7.80), while T_9 Control (No boiling) showed the lowest score (5.97). The decline in flavour during storage may be attributed to some oxidative changes and individual sensory perception. This finding is in line with the results reported by Kaur and Singh (2021) in kinnow (*Citrus nobilis* X *Citrus deliciosa*) peel candy, Kumar *et al.* (2022) in orange (*Citrus reticulata* L.) peel candy during the storage of 90 days and Nagar and Rastogi (2022) who also discovered decreasing trend in flavour of fruit peel candies during the storage of 30 days, respectively.

Overall acceptability

After 45 days of storage, the kinnow peel candy boiled three times for 8 to 10 minutes (T_2) was found to have the highest overall acceptability score of 7.43, while the control group (T_9) had the lowest score of 5.90 (Fig. 5). Throughout the storage period, the mean score for

overall acceptability dropped from 7.75 to 6.16. This decline in acceptability could be attributed to the reduction in scores for the candy's colour, texture, and flavour. The sensory attributes of the candy are crucial in determining its overall acceptability as they directly affect the consumer's perception of the product. The results are aligned with the investigation of Verma *et al.* (2023), who examined the osmotically dehydrated karonda (*Carissa carandas* l.) and found decline in overall acceptability during 90 days of storage, while Purewal *et al.* (2022) and Kumar *et al.* (2022) studied the ready to serve kinnow-amla beverages and orange (*Citrus reticulata* L.) peel candy, and proclaimed decrease in overall acceptability during the storage of 90 days, respectively.

Conclusion

The present study found that multiple boiling of kinnow peel (8-10 minutes) cooked in 75 ^{0}B syrup (sugar) solution for 5 to 8 minutes then steeped in syrup (sugar) for 24 hours (treatment: T_2) produced the highest quality candies in terms of various proximate, biochemical and sensory parameters, including overall acceptability, TSS, titratable acidity, ascorbic acid, total sugar, and reducing sugar, during a 45-day storage period at ambient temperature (15 ^{0}C to 25 ^{0}C). However, the study also identified limitations in the storage stability of the candies at ambient temperature, as they deteriorated in composition and sensory properties due to the development of orange colour and hardening effects. Refrigerated storage may help to extend the shelf life of the candies. The kinnow peel could be used as a food processing sector raw material. Furthermore, this study contributed to the sustainable development goals (SDGs) for good health and well-being as kinnow peel is also nutritious as their fruits and sanitation by utilizing the peel waste and helps reduce pollution load on the environment. Future research could explore using natural extracts or other methods to improve further the sensory properties and storage stability of kinnow peel candies and investigate the feasibility of large-scale production and commercialization.

ACKNOWLEDGEMENTS

The authors deeply appreciate the Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab (India) for continuous support in conducting this research study.

Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Aggarwal, P., Kaur, S. & Kaur, N. (2022). Intermediate moisture kinnow bar from low grade kinnow mandarins: Phytonutritional profile, morphological characterization, and storage stability. *Food Bioscience*, 49, 101837. DOI: 10.1016/j.fbio.2022.101837
2. Ali, M. R., Mohamed, R. M., & Abedelmaksoud, T. G. (2021). Functional strawberry and red beetroot jelly candies rich in fibers and phenolic compounds. *Food systems,* 4(2), 82-88. DOI: 10.21323/2618-9771-2021-4-1-82-88
3. AOAC.2005 Official methods of analysis. 18th ed, Association of Official Analytical Chemists, Benjamin Franklin Station, Washington, DC.
4. Arias, A., Feijoo, G., & Moreira, M. T. (2022). Exploring the potential of antioxidants from fruits and vegetables and strategies for their recovery. *Innovative Food Science & Emerging Technologies*, *77*, 102974. DOI: https://doi.org/10.1016/j.ifset.2022.102974
5. Bansode, S. V., Chavan, U. D., Godase, S. N., & Kotecha, P. M. (2021). To study the effect of storage on chemical and sensory characteristics of ginger candy. *IJCS*, *9*(1), 1589-1599. DOI: 10.22271/chemi.2021.v9.i1w.11454
6. Costea, L., Chițescu, C. L., Boscencu, R., Ghica, M., Lupuliasa, D., Mihai, D. P., ... & Gîrd, C. E. (2022). The polyphenolic profile and antioxidant activity of five vegetal extracts with hepatoprotective potential. *Plants,* 11(13), 1680. DOI: 10.3390/plants11131680
7. Halim, Y., Evelyne, C., Rosa, D. & Ramli, S. (2022). Development of Roselle (*Hibiscus sabdariffa* L.) Calyx Jelly Candy. Caraka Tani: *Journal of Sustainable Agriculture,* 37(2), 357-372. DOI: 10.20961/carakatani.v37i2.61537
8. Hien, D. T. & Nguyet, H. T. M. (2021). Effects of vacuum frying on the quality of king orange peel in manufacture of chocolate candy fillings. *Food Science and Applied Biotechnology*, 4(2), 156-165. DOI: 10.30721/fsab2021.v4.i2.110
9. Kaur, H. & Singh, G. (2021). Evaluation of Various Methods of Preparing Kinnow (Citrus nobilis X *Citrus deliciosa*) Peel Candy. *Annals of Biology*, 37(2), 267-271.
10. Khandare, V. S. & Syed, S. J. (2019). Effect of various treatments on physico-chemical composition of Indian gooseberry (Emblica officinalis) candy during storage. *Journal of Pharmacognosy and Phytochemistry*, *8*(4), 2580-2586.
11. Kumar, R., Deb, P., Dewangan, R. K. & Kumar, P. (2022). Preparation and quality assessment of orange (*Citrus reticulata* L.) peel candy. *The Pharma Innovation Journal*. 11(12): 2958- 2963.

12. Lu, X., Zhao, C., Shi, H., Liao, Y., Xu, F., Du, H., ... & Zheng, J. (2023). Nutrients and bioactives in citrus fruits: Different citrus varieties, fruit parts, and growth stages. *Critical Reviews in Food Science and Nutrition*, *63*(14), 2018-2041. DOI: 10.1080/10408398.2021.1969891
13. Mohanta Varsha, Ina Mukherjee & Jayati Pal Chattopadhyay (2021). Waste product utilization: preparation of candy from orange (Citrus sinensis) peel. *International Journal of Agricultural and Applied Sciences*, 2(2):114–119.DOI: https://doi.org/10.52804/ijaas2021.2217
14. Muzzaffar Shruthi, S. & Bahadur, V. (2020). Standardization of sugar levels on Physico-chemical properties of peel candy of Karna Khatta (*Citrus karna*) during storage. *Journal of Pharmacognosy and Phytochemistry*, 9(5), 3030-3034.
15. Muzzaffar, S., Baba, W. N., Nazir, N., Masoodi, F. A., Bhat, M. M. & Bazaz, R. (2016). Effect of storage on physicochemical, microbial and antioxidant properties of pumpkin (*Cucurbita moschata*) candy. *Cogent Food and Agriculture,* 2: 1163650. DOI: 10.1080/23311932.2016.1163650
16. Nagar, V. & Rastogi, M. (2022). Preparation and Nutritional Quality Evaluation of Fruit Peel Candies. *Journal for Research in Applied Sciences and Biotechnology*, 1(3), 57-64. DOI: https://doi.org/10.55544/jrasb.1.3.8
17. NHB (2022). NHB area and production of horticulture crops for 2021–22. doc202271470601pdf (static.pib.gov.in)
18. Panwar, D., Panesar, P. S., & Chopra, H. K. (2021). Recent trends on the valorization strategies for the management of citrus by-products. *Food Reviews International*, 37(1), 91–120. DOI: 10.1007/s13197-023-05743-x
19. Purewal, S. S., Kamboj, R., Sandhu, K. S., Kaur, P., Sharma, K., Kaur, M., & Siroha, A. K. (2022). Unraveling the effect of storage duration on antioxidant properties, physicochemical and sensorial parameters of ready to serve Kinnow-Amla beverages. *Applied Food Research*, 2(1), 100057. DOI: 10.1016/j.afres.2022.100057
20. Rafiq, S., Singh, B. & Gat, Y. (2019). Effect of different drying techniques on chemical composition, color and antioxidant properties of kinnow (*Citrus reticulata*) peel. *Journal of food science and technology*, 56, 2458-2466. DOI: 10.1007/s13197-019-03722-9
21. Rezagholizade-Shirvan, A., Shokri, S., Dadpour, S. M. & Amiryousefi, M. R. (2023). Evaluation of physicochemical, antioxidant, antibacterial activity, and sensory properties of watermelon rind candy. *Heliyon*, *9*(6). DOI: 10.1016/j.heliyon.2023.e17300
22. Sharma, M., Usmani, Z., Gupta, V. K. & Bhat, R. (2021). Valorization of fruits and vegetable wastes and by-products to produce natural pigments. *Critical Reviews in Biotechnology*, 41(4), 535-563.DOI:https:// doi.org/10.1080/07 38855 1.2021 .1873240
23. Shorbagi, M., Fayek, N. M., Shao, P. & Farag, M. A. (2022). Citrus reticulata Blanco (the common mandarin) fruit: An updated review of its bioactive, extraction types, food quality, therapeutic merits, and bio-waste valorization practices to maximize its economic value. *Food Bioscience*, *47*, 101699. DOI: 10.1016/j.fbio.2022.101699
24. Singh, B., Singh, J. P., Kaur, A. & Yadav, M. P. (2021). Insights into the chemical composition and bioactivities of citrus peel essential oils. *Food Research International*, 143, 110231. DOI: 10.1016/j.foodres.2021.110231
25. Suman, K. M., Gupta, A., Vaidya, D. & Ranjan, K. (2021). Standardization of formulation for the preparation of ginger supplemented jelly candies. *Pharma Innov J*, *10*, 608-613.
26. Teigiserova, D. A., Tiruta-Barna, L., Ahmadi, A., Hamelin, L. & Thomsen, M. (2021). A step closer to circular bioeconomy for citrus peel waste: A review of yields and technologies for sustainable management of essential oils. *Journal of Environmental Management*, 280, 111832. DOI: 10.1016/j.jenvman.2020.111832
27. Urooj, A. (2021). Development of fruit candies from wood apple (*Limonia acidissim*) and passion fruit (*Passiflora edulis*), nutritional and acceptability study during storage. *Journal of Food and Dietetics Research*, *1*(1), 14-18. DOI: 10.48165/JFDR.2021.1103
28. Verma, S., Bhat, A., Gupta, N. & Sharma, S. (2023). Effect of storage on chemical characteristics of osmotically dehydrated karonda (*Carissa carandas* l.). *Plant Archives*, *23*(1), 280-284. DOI: 10.51470/PLANTARCHIVES.2023.v23.no1.047
29. Wedamulla, N. E., Fan, M., Choi, Y. J. & Kim, E. K. (2022). Citrus peel as a renewable bioresource: Transforming waste to food additives. *Journal of Functional Foods*, *95*, 105163. DOI: https://doi.org/10.1016/j.jff.2022.105163
30. Yaqoob, M., Aggarwal, P. & Ahluwalia, P. (2020a). Enhanced functional properties and shelf stability of muffins by fortification of kinnow derived phytochemicals and residues. *Think Ind. J.* 22: 1422–1445. DOI: 10.1007/s11694-021-00827-8
31. Yaqoob, M., Aggarwal, P., Aslam, R. & Rehal, J. (2020b). Extraction of bioactive from citrus. In: Green Sustainable Process for Chemical and Environmental Engineering and Science, Inamudin, Asiri A. M. and Isloor, A. M. (eds.). Elsevier, Amsterdam. pp. 357–377. DOI: https://doi.org/10.1016/B978-0-12-817388-6.00015-5

32. Zhou, S. & Huang, G. (2023). Extraction, structural analysis and antioxidant activity of aloe polysaccharide. *Journal of Molecular Structure*, 1273, 134379. DOI:https://doi.org/10.1016/j.molstruc.2022.13 4379
33. Zia, S., Khan, M. R., Shabbir, M. A. & Aadil, R. M. (2021). An update on functional, nutraceutical and industrial applications of watermelon by-products: A comprehensive review. *Trends in Food Science & Technology*, 114, 275-291. DOI: 10.1016/ j.tifs.2021.05.039