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Review Article

Kinnow: Nutritionally Rich Functional Food for Value Addition

Andleeb Zahra[1], Tahira Batool Qaisrani[1], Matlob Ahmad[1], Talat Bilal[2]
[1]*Department of Agricultural Engineering and Technology, Faculty of Agricultural Sciences, Ghazi University, Dera Ghazi Khan, Pakistan.*
[2]*Department of Animal Sciences, Ghazi University, Dera Ghazi khan, Pakistan.*

ABSTRACT

Kinnow mandarin, a variety amongst citrus fruits is preferred for refreshing flavor pleasing aroma and bright color. It is rich in vitamins B complex and vitamin C, with remarkable minerals like calcium, phosphorus and other bioactive compounds. These compounds proved to have antioxidant, anti-inflammatory and antimicrobial activities. Pakistan is amongst of top kinnow producing countries on globe. Unfortunately, an ample quantity of its produce is wasted due to mishandling at post-harvest stage and lack of keeping facilities in under developing countries. This fruit is mainly processed to prepare beverages and juice-based products. One of the hindrances to its processing may be the presence of bittering compounds. Various de-bittering techniques can be opted to resolve this issue. Keeping in view its importance a lot of work has been done so far to prevent its losses. Kinnow fruit possesses a number of industrial and medical applications as well. Hence the processing is increasing in terms of techniques and products resulting in preparation of a number of value-added food products. The nutritional value of the kinnow prescribes its use in formulating a number of food products like ready to serve drinks, juices, squash, nectars, different blends, powders, candies, fermented products etc. This review covers information about kinnow production, harvesting, storage, post-harvest losses and their solutions globally. The article also highlights the nutritional importance, variety of products and techniques being applied in kinnow processing.

Keywords: Kinnow Mandarin, Value-added Products, Functional Ingredients, Nutrition.

Correspondence
Andleeb Zahra
guv0351@gudgk.edu.pk

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INTRODUCTION

Citrus belongs to the Rutaceae family (Rue family) consisting of nearly 140 genera and around 1300 species. The important ones are *C. limon* (Lemon), *C. sinensis* (Orange), *C. reticulata* (tangerine), *C. aurantium* (sour orange), *C. paradisi* (Grapefruit), C. aurantifolia (lime), C. medica (Citron) and C. grandis (shaddock). The plants of these species vary from large evergreen shrubs to small trees (5-15 m tall) (Nath et al., 2013; Singh et al., 1983). Initially this hybrid variety was developed in the University of California Citrus Experiment Station in 1935 and introduced in the subcontinent in early 1940,s. Kinnow mandarin is formed by cross breeding of "King" and "Willow Leaf" varieties. Scientific name of King is *Citrus Nobilis* and willow leaf is *Citrus Deliciosa*. The kinnow fruit possess characteristic bright color, refreshing flavor and enticing taste (Anticona et al., 2021; Bezman et al., 2001; Joshi et al., 1997; Khalid, 2013; Premi et al., 1994; Putnik et al., 2017; Sharma et al., 2007). This variety was introduced by J.C. Bakhshi in 1954 at the Punjab Agricultural University, Regional Fruit Research Station, Abohar (Aulakh et al., 2008).

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The kinnow fruits contain high amount of juice and has a refreshing flavor and sweet taste. It also possesses properties like thirst quenching and also possess pleasing aroma. The fruit is bright in color and good in appearance (Yaqoob et al., 2020). The shape of the Kinnow is oblate, having no neck part. The fruit has an average diameter of 68 mm and height of 55.2 mm having flat and orangish rind which is slightly visible along with the oil glands. The peel of the kinnow fruit is comparatively thin and somewhat adherent at maturity having thickness of approximately 2.5mm. Fruit contain smooth flesh textured segments, normally 10-11 segments are present in a single fruit having weight of 145g yielding nearly 49 % of the juice (Rattanpal et al., 2017).

Kinnow (mandarin) is considered as an important fruit, having vitamins and also minerals (Yaqoob et al., 2020). Kinnow contains high quantities of vitamin B, C, calcium and phosphorus. This proved that kinnow fruit had number of industrial and medical applications (Mahawar et al., 2020).

The specific quality features that separate the kinnow from other varieties of citrus includes its peel containing a lot of oil glands, easy to peel off as the bonding of skin with inner part of fruit is less, containing large amount of juice, its sections are easily separable and also provide a good amount of vitamin c to the body when consumed. The inner pulp portion can be used for sauces, jams, and also for making desserts (Yaqoob et al., 2020).

Economic Importance

The export of kinnow mandarin from Pakistan has increased because of its demand of fresh fruit consumption. The fruit was mainly exported to Middle East, Russia and South East Asia. The amount of the kinnow fruit exported in 2010 was around 250,000 tons and earned the 120 million dollars in foreign exchange. Processing plants and export units had been established in Sargodha over the last two decades because of the common perception that kinnow fruit available in that area had better quality.

Harvesting

Kinnow is delicate in nature, perishable food commodity, having short shelf life of 1-2 weeks at ambient temperature. The fruit needs sharp contrast of warm and cool environment. This is necessary for obtaining high quality fruit and for better cropping (Rattanpal et al., 2017).

It is important to determine the maturity stage correctly to prevent postharvest losses (Hossain, 2015). In maintaining the shelf life, proper maturity stage plays an important role (Rokaya et al., 2016). The studies are mostly done on ripening stages to understand the changes occurring during physiological maturity (Rokaya et al., 2016; Singh et al., 2016a). If the fruits are not harvested at the appropriate maturity stage, physiological disorders develop during the storage ultimately reducing the shelf life of the fruit (Kashyap et al., 2020).

On commercial basis, maturity indices are variable as depending on environmental conditions, ripening stage, varieties and growing region (Lado et al., 2014). The measurement of fruit maturity is pre requiste in order to proper use and to get the maximum benefit regarding sensory attributes and nutritional value of the fruit (Deshmukh et al., 2016). The confirmation of fruit maturity is difficult as it depends on the internal and external changes occurring during the development, growth and maturity. The changes in color of fruit flesh and peel define the maturity of fruit (Kashyap and Banu, 2019). For the proper and precise evaluation of fruit maturity, physical, chemical and visual parameters are evaluated. These are acidity, total soluble solids, and ascorbic acid as an alternative to quality evaluation.

Kinnow is usually harvested by cuttings/clippers and collected on the ground in crates/bags which eventually represent a substantial loss after harvest. Most of the studies available in the literature of Khasi mandarin were carried out only across ripening stages to understand the physiological maturity. However, till now no systematic research work has been reported throughout the development phase (right after fruit setting) in Khasi mandarin and to understand the significance of the physicochemical parameters contributing towards the best quality fruit (Rokaya et al., 2016; Singh et al., 2016a).

Storage

Research was conducted in India to study the storage life of kinnow. Hot water and sodium bicarbonate were used as treatments and their effect on storage life was accessed. The fruit was treated with water having various temperature treatments (45 ℃, 50 ℃ and 55 ℃), different concentrations of $NaHCO_3$ (2 - 3 percent) and also their combinations were tested. Untreated fruits were used as control. Kinnow were placed at room temperature for about 21 days. The study revealed that the acid content decreased with the time during the storage, the decrease in fruit weight, total soluble solids, as well as the incidence of illness increased. The changes related with the storage length of Kinnow mandarin were reduced by hot water treatment having 50°C temperature. This was effective if applied but also effective when applied with sodium bicarbonate (2 percent). This treatment improved the quality and shelf life of kinnow mandarine. The chemical and physical characteristics were decreased by using the hot water having temperature more than 50°C. This reduced the benefits of this treatment on kinnow fruit (Singla et al., 2018).

The shelf life of kinnow mandarin reduced due to the physiological disorders. The disorders included rind staining, weight loss, and chilling injury. These three disorders were examined in this study. The samples of kinnow were coated with polyethylene-based wax (PBW) and shellac-based wax (SBW). The samples were stored at 2, 5, 8 °C and also at ambient temperature. The influence on these disorders was evaluated. The difference in temperature affected the disorders significantly. Results of the samples placed at 5 °C shown reduction in disorders as compare to the other samples. The samples coated with shellac wax were more likely to suffer from the disorder of rind stain and chilling injury. The samples coated with the polyethylene wax showed better results as the production of acetaldehyde and ethanol was reduced. Thus, the research concluded that the mandarin coated with the polyethylene wax and stored at 5 °C showed increase in shelf life (Bajwa and Anjum, 2007).

Similar research was conducted in Pakistan and different coatings for the kinnow were prepared. The effect of these coatings was studied. Two types of coatings were used, one was prepared from the natural ingredients and the other was the synthetic coating. The ingredients used for the preparation of natural were shellac, water, rosin, gum arabic, and ethanol from sugar industry. In perspective of product acceptance, consumer preferred the natural ones or prepared from the natural ingredients as compare to the artificial products. For the synthetic coating the polyethylene-based wax was used that was also containing the ammonia. All the prepared samples were stored for 63 days at 5 °C and the level of humidity was 85-90%. According to the results of this research, changes in the firmness, vitamin C content, sensory properties and physiological losses were reduced significantly by using the natural and synthetic coatings. Thus, the study revealed that the use of natural coatings would be better to be used for the coating of kinnow (Ali et al., 2015). Cold storage treatment was performed to extend the shelf life of the kinnow. The samples were stored at 4°C and the effect of cold storage was evaluated. Total soluble solids were preserved better during the cold storage. The value of TSS obtained from juice was 11.49 %. By using the technique of cold storage, the postharvest losses were reduced. During the storage period, less reduction in weight of fruit, juice content was observed. Thus, an effective method of preserving the fruit. Study suggested that the fruit could be stored for about 42 days at temperature of 4 °C and no change in visual appearance was observed. Samples stored at low temperature showed better retention of carotenoids in peel and sugar acid ratio in juices (Kashyap and Banu, 2019).

Postharvest Losses and Their Measures

Postharvest management becomes difficult because of its rapid deterioration resulting major losses to the economy and to the farmers (Rokaya et al., 2016). Temperature is an important factor to be maintained after harvesting in order to maintain the quality of the fruit (Tietel et al., 2012).

The fruits that are damaged during the harvesting are not acceptable for marketing or consumption. At farm level the postharvest losses are considered to be the highest, as 32.4 percent of the total produce of kinnow were lost in India in 2015. During picking, packaging, carrying, loading and transportation (19.6%, 3.5%, 2.2%, and 7.1%) kinnow fruit is wasted (Ahmed et al., 2015). The overall harvest and post-harvest losses of kinnow are between 25 and 30 per cent, according to Singh et al. (2016a). However, with the proper processing of kinnow into other products with better quality, this number of losses can be effectively decreased.

Regardless of the considerable rise of global food production, almost half of the population of the less developed countries have insufficient access to food. Labor is involved in the production and marketing of citrus fruits (Ahmed et al., 2015). In Pakistan, kinnow production industry is affected up to 10-15% postharvest losses from place of harvest to consumption due to inefficient handling, transportation, storage methods, and even the technical expertise.

Fruits contain around 80-90 % water and fall under the category of perishable food commodity. During the fruit preparation process, fruits are washed. As major portion of wax which is present on the fruit naturally is removed during the washing resulting in increased moisture evaporation rate from. Spoilage increased due to contamination of flesh that could be through the skin. Browning, off flavor development and texture breakdown decreases the quality and makes fruit vulnerable to microbial attack (Ali et al., 2015; Dhall, 2013). The research data from Iran infers that around 28-31% of total citrus fruit was wasted every year. The loss was in terms of quality as well as in quantity. About 15 – 18 % loss of fruit both in quality and quantity occurred mainly because of improper storage of the fruit after harvesting and improper packaging (Baghkhandan, 2006; Miri et al., 2017; Mollapur et al., 2016).

The availability of fruit during the off-season is extremely low due to its poor shelf-life of 8–10 days, despite its commercial significance and nutritional advantages. Kinnow's major post-harvest issue is the absence of adequate marketing channels and inadequate management methods after harvest. Compared to other fruits of citrus, the shelf-life quality of kinnow is low and cannot be carried inside gunny bags. As the production is increased and continuous, ample amount is transported to the market from different orchards. This results in sorting of only good quality kinnow for fresh consumption while discarding the low-quality fruit. Shelf life increased significantly by applying different treatments after harvesting (Rokaya et al., 2016). Different feasible techniques have been implemented for improving fruit shelf-life after harvest in recent years, such as fungicide usage, cold storage, MAP, controlled atmosphere, use of wax coatings, anti-transpirants, growth retardants, applying irradiation, and by using different kinds of packing materials (Miri et al., 2018; Rokaya et al., 2016).

Structural Composition

The kinnow fruit, morphologically divided as peel and pulp. Flavedo is the outer colored part of the fruit containing pigments in the form of oil glands and chromoplast. The inner whiter part of the fruit is called albedo. Pectin and phytochemicals are abundantly present in the flavedo and albedo portion as compare to the other parts of the fruit. The pulp is the edible part of the fruit, containing many segments and sacs filled with the juice. The compositional study resulted that kinnow contains 85 to 90 % water, 6-9 % sugars and > 2 % acids, pectins, minerals, essential oils, protein, fiber and fat contents (Izquierdo and Sendra, 2003).

Fruit is covered with peel as it provides protection to the pulp of the fruit from the outer environment. The pulp of kinnow fruit contains seeds and juice sacs. A layer of cuticle is present on the epidermal layer (flavedo) of the fruit, containing many oil glands in which essential oil is present giving specific aroma to the fruit. Color providing components are also present in the flavedo portion in the form of chromatophores. Fruit appears green initially while orange when fully matured. Albedo (spongy structure) of the fruit contains parenchymatous cells and this lies below the flavedo. Cells are unevenly distributed with slightly organized intercellular spaces. From albedo the citrus pectin is recovered which is water soluble fiber.

The inner part of the fruit contains many segments, which are separated by a thin layer of epidermal tissues. Spindle shaped juice sacs are also present along with the seeds. The juice vesicles in each segment are attached to the segmented wall and further attached to the peel by means of fine fiber threads. Centrally present juice sacs contain the droplets of oil which are implanted in the tissues. Segment membrane and core collectively known as “Rag” (Petracek and Davis, 1996).

Nutritional Importance

The recent trends in food consumption indicate that health assurance is the vogue behavior towards food selection. Studies have shown that the consumption of fruits can play an important role in reducing the risk of chronic diseases including diabetes, cancer, Alzheimers, cardiovascular diseases. Natural antioxidants are present in higher ratio in fruits. These compounds reduce the risk of chronic diseases occurring as a result of oxidative damage in the human body (Liu, 2003; Temple, 2000; Willett, 2002). Fruits from citrus family contain phytochemicals such as phenolic carotenoids, many nitrogenous compounds, and alkaloids. These compounds are responsible for performing bioactivities like anti-fungal, antiviral, antioxidant and anti-bacterial (Dillard and German, 2000).

The world’s important fruit crop, citrus is consumed as whole fresh fruit and fresh juice because of its high nutritional value and refreshing quality attributes. The increased consumption of the citrus fruits and fruit -based products is associated to decrease the occurrence of a number of diseases (Joshipura et al., 2001). In Finland, research was conducted and the results showed that the consumption of orange reduced the chances of asthma (Knekt et al., 2002). The citrus products are considered as anti –inflammatory, antifungal, inhibit the formation of blood clot and possess antitumor properties (Ben-Yehoshua et al., 1995; Middleton, 1994).

The citrus fruits contain hesperidin, bioflavonoids and naringin. According to the reports, these compounds have pharmacological and biological properties including lipid managing, anti-carcinogenic, anti-oxidant and anti-inflammatory activities (Bok et al., 1999; Choi et al., 2001; Okwu, 2008). The progression of hyperglycemia is prevented by naringin and hesperidin (Jung et al., 2004) whereas naringin acts as potential therapeutic agent to prevent and cure osteoporosis and debris associated osteolysis (Li et al., 2014; Wei et al., 2007). Naringin, hesperidin and limonene normally called as polyphenols and limonoid aglycones have anticancer and anti-inflammatory activity (Xu et al., 2019).

The citrus plants have the ability to synthesize and accumulate phytochemicals in their cells including low molecular phenolics (Rehman et al., 2019). The presence of these bioactive compounds (flavanone glycosides, hydroxycinnamic acids) (Ross et al., 2000), vitamin C (Knekt et al., 2004), and carotenoids (Craig, 1997), enhance the importance of fruit. In citrus fruits, ¾ th of ascorbic acid is present in peel, pulp and also in seeds (Mann and

Aggarwal, 2013; Nagy, 1980). Research has shown that phenols, amino acids, pectin, carotenoids, ascorbic acid and flavonoids have beneficial effects and are effective in reducing the degenerative diseases (Wang et al., 2014).

The famous citrus fruits like mandarins, oranges, tangerine, lemon and grapefruits are included among the fruits containing high amounts of ascorbic acid (Vit. C), phenols, dietary fiber, pectin, citric acid, carotenes and minerals like phosphorous and calcium as stated by Ullah et al. (2015). According to the studies, citrus fruits contain soluble dietary fiber in higher amounts than other fiber sources of plant origin (Finglas et al., 2014; Ignat et al., 2011). According to the nutritionists, the daily dietary intake of fiber should be 25-38 g per day for adults (Food and Nutrition Board, 2001, Washington, D.C). The limonene and naringin are helpful in providing the fiber content. Both the components have health promoting benefits although being responsible for the bitterness (Xu et al., 2019). The consumption of these components varies on individual basis because of the different diet patterns. According to the data collected upon per capita consumption in US in 1998, the intake of D-limonene was 0.27 mg/kg body weight/day. According to the EFSA, the mean intake of naringin per capita was 280 µg/person/day, which remained below the threshold of concern for Class II substances recommended up to 540 µg/person/day (Additives and Feed, 2011). According to the results from researchers, various parts of kinnow fruit can be used as functional food possessing medicinal properties and in cosmetics. Kinnow peel contain flavonoids and also possess health benefits. Flavonoids like neo hesperidin and hesperidin, used as natural sweeteners when converted to dihydrochalcones (Yaqoob et al., 2020). Naringin, because of its bitter taste, used as flavoring agent for sweets, beverages and bakery goods (Giannuzzo et al., 2003). Anthocyanins are used to add color to dairy foods, sweets, and confectionaries. Kinnow fruit and juice are an important component of a healthy diet. The variety of nutrients and bioactive compounds present in citrus are proved as health promoters by protecting against many chronic diseases (Baghurst, 2003). The oxidation reactions produce free radicles which have the ability to attack the healthy cells of the body thus resulting in loss of structure as well as their functions. These damaged cells contribute to ageing and degenerative conditions, such as cancer, cardiovascular diseases, cataracts, brain dysfunction and decreased immunity (Yadav et al., 2016). Antioxidants have the ability to control the free radicles produced either by neutralizing them or by stopping their reactions (Devasagayam et al., 2004). Components present in the fruit possessed antioxidant properties and capable of forming electrons which are delocalized and also unpaired. Phenoxyl radical is stabilized by the components of kinnow having antioxidant potential (Babbar et al., 2015).

Antioxidants are classified according to their sources as natural and synthetic. Artificial antioxidants are used in food industry in order to prevent the oxidation of food components and lipid peroxidation. Butylated hydroxytoluene (BHT), tertbutyl hydroquinone (TBHQ) and Butylated hydroxy anisole (BHA) is some commonly used artificial antioxidants. According to the research conducted in last few years, many issues had been raised regarding their safety and toxicity. These may cause the inflammation of liver as the activities of the enzymes are influenced by these compounds and also carcinogenicity. The natural antioxidants are safer to use, having no harmful effects on health and also possessed higher solubility (Babbar et al., 2011), including carotenoids, vitamins, flavonoids, and many others (Yadav et al., 2016). A number of compounds are present in citrus fruits including acids (citric, ascorbic), minerals, and flavonoids like, naringin, hesperidin, neo hesperidin, rutin, naringenin, tangeretin and nairutin (Kawaii et al., 1999; TANIZAWA et al., 1992).

Kinnow, a great source of compounds that are considered as bioactive. These compounds possess many health improving properties by acting as free radical scavengers, antimicrobial agents, anti –inflammatory, antimutagenic neuroprotective properties etc. Plant based substances having free radical scavenging and antioxidant properties have gained importance now a days as they are rich in polyphenolic compounds (Mathur et al., 2011; Singh et al., 2016b). Many bioactive compounds are present in peel of citrus like phenolic acid and flavonoids (Bocco et al., 1998; Giannuzzo et al., 2003; Manthey and Grohmann, 2001). The components generally known as flavonoids have antioxidant potential and are capable of bonding an electron thus blocking the formation of free radicals. The flavonoids present in the kinnow fruit form tautomeric dislocation thus preventing the reactions that results in the formation of radicals that are free to react (Okwu, 2008). These are neuroprotective, they modulate the activities and also improves health of mind like depression, mood, etc. Hesperidin plays an important role in the protection of Neurons from many disorders (Castro-Vazquez et al., 2016).

Research data infers that the kinnow fruit is rich in its nutrition aspect containing acids, carotenoids, terpenes, phenolic compounds, phytosterols, fiber, and minerals. Hence, providing health benefits and possess ability to protect the body against various diseases. The effect of diseases like cancer, cardiovascular diseases, inflammation can be reduced by the intake of kinnnow juice and its products (Bhardwaj and Nandal, 2014).

Ascorbic Acid

The juice of the fruit contains 60-70 mg of vitamin C thus proved good for health. This enables the fruit to have antioxidant property (Ullah et al., 2015). The amount of ascorbic acid in juice section and segment varies from 25.4 to 45.3 mg/100 g FW among different varieties of citrus selected for the research. The mandarin variety contain 45.3 in juice section, 14.2 in membrane segment and 38.9 in segment of the fruit used in the research (Abeysinghe et al., 2007).

Ascorbic acid acts as an antioxidant. This boosts the immunity, protect against scurvy, cataracts, cancer, heart diseases and also from other infections. Involved in maintaining the skin collagen and also prevent from iron deficiency "anemia" by elevating the non-heam iron absorption to nearly double. The absorption of zinc and iron are stimulated by vitamin C. In hydroxylation reactions this act as a cofactor. These reactions involve the biosynthesis of catecholamines, cholesterol, L-carnitine, peptide hormones and amino acids. In plasma, act as radical scavenger and provide protection to the cells from oxidative damage. It also protects DNA from mutation that could be caused by oxidation. Lipids are also protected from pro-oxidative damage. If the transition metals like iron or copper are present this act as pro-oxidant and kill the cancer cells. Malignancies in humans are reduced. This prevents apoptosis, reduce the risk of cataract formation, improve neurotransmission and act as anti-inflammatory agent (Devaki and Raveendran, 2017; Grosso et al., 2013).

Carotenoids

The carotenoids were abundantly present in mandarin as compare to the other varieties of citrus (Abeysinghe et al., 2007). This was also the results of research done by Fanciullino et al. (2006). According to the results of research done in China, the juice section and segment contained higher amounts of carotenoids. The content of carotenoids in the mandarin variety was 1.36 in juice section, 0.62 in membrane segment, 1.21 mg BCE/100 g FW in segment of the fruit (Abeysinghe et al., 2007).

Beta carotene provides protection from infections, cardiovascular diseases, cancer and also act as a precursor of vitamin A. The formation of plaque in the arteries is slowed down by the action of carotenoids. By the action of these compounds the free radicals are in activated, act against oxygen species which are reactive. Involve in the modulation of gene expression. This provides protection in conditions like diabetes, inflammation, CVD, apoptosis, fibrosis, oxidative stress, hepatic steatosis etc. Research has shown that lutein has anti-inflammatory properties, improve the heart and eye health. Macular diseases which are age related are also prevented (Buscemi et al., 2018; Elvira-Torales et al., 2019; Jiao et al., 2019).

Terpenes

Limonene plays important role in human body as it protects the human body from pancreatic and mammary tumor, act as anti-cancer agent, dissolve gallstones and also involve in the maintenance of cholesterol level. It prevents the DNA from damage, also involves in the DNA repair and also reduces the mutation which results in cancer. This activates the detoxifying enzyme system. This act as antimicrobial agent and effective against those microorganisms which have developed resistant against antibiotics like yeast and fungi. This act as anti–inflammatory agent, anti-tumorigenic and neuroprotective agent (Cho et al., 2017; Kandi et al., 2015).

Phenols

The total phenolic content in juice, segment membrane, and segment were, 281, 801, 318 mg CAE/100 gFW (Abeysinghe et al., 2007). According to the research conducted in 2004, citrus fruit is a source of hydroxy-cinnamic acids, flavanone glycosides, which act as bioactive compound (Caro and Cederbaum, 2004; Gorinstein et al., 2004). The health benefits of phenols reported are antiviral, antioxidant, anti- inflammatory etc. The composition of kinnow reveals its effectiveness against viral infections, allergic problems and ulcer (Cory et al., 2018).

The research conducted in China showed that the total flavonoids in mandarin were 64.8 in juice segment, 278 in membrane segment, and122 mg RE/100 g FW in segment (Abeysinghe et al., 2007). Flavonoids (flavanols, flavanols, flavanones, flavones), stilbenes, phenolic acid, tannins and coumarines are included in phenolic compounds (Liu, 2004). For the deduction and quantification of flavonoids, high performance liquid chromatography, either normal or reversed phase was used (Bronner and Beecher, 1995; Kanaze et al., 2003).

Flavonoids present in kinnow play anti-fungal role and also prevent cancer. These are Effective against allergies and also against heat stroke. These have neuroprotective properties, modulate the activities and maintain the mental health. Also antitumor, antiplatelet, antioxidant, anti-inflammatory, antillergic, antiproliferative, antiviral, antidiabetic, antineoplastic, gastroprotective, hepatoprotective and anticarcinogenic properties (Baghurst, 2003; Castro-Vazquez et al., 2016; Tanwar and Modgil, 2012; Yao et al., 2004). The flavonoids provide more health benefits as compare to dietary ones (Ullah et al., 2015).

Fibers

Fiber provides many benefits. Fiber is also present in kinnow. This provides protection against many diseases including gut diseases, ulcers, cancers, prevent strokes heart diseases, diabetes. This is also effective in lowering the cholesterol level (Anderson et al., 2009; Li and Komarek, 2017).

Minerals

Kinnow fruit contain minerals like potassium, calcium, iron and phosphorous (Ahmed et al., 2015). The potassium helps to regulate the blood pressure. This Protect against bone loss associated with ageing, useful in Kidney stone reduction and decrease death ratio due to cardiovascular disease (CM, 2013; He and MacGregor, 2008).

Value Added Products

Kinnow fruit, around 95 % are consumed as a whole mainly for table purpose while only 5 % of total production is utilized for the processing of either juice or juice concentrate. During the peak season, the market contains surplus amount of product thus reducing the prices (Khandelwal et al., 2019). The citrus fruits are used for direct consumption but in last few years the trend has been changed as decrease in fresh fruit consumption is being observed. As far as demand increased the oranges were converted into different forms like flakes, slices and powder by the method of dehydration. New citrus products are being developed by the researchers at public and private sector keeping in view the recent trends to enhance their use by the consumers (Castro-Vazquez et al., 2016). Research was conducted in Pakistan in 2015 to study the effect of different blends. These were prepared by mixing extracts of ginger and lemon with carrots and also with kinnow. Ready to serve drinks were prepared and studied for the period of three months at refrigeration temperature. Six samples with different concentrations of ginger and lemon were made having half liter of carrot and kinnow juice. The samples were tested for moisture, pH, vitamin C, sugars soluble solids etc. The sugar: acid ratio and pH were reduced with time. The sample with 20 ml of ginger and 80 ml of lemon having the same quantity of kinnow and carrot was acceptable in terms of taste and flavor (Ullah et al., 2015).

According to the research, there is variety of benefits of powders prepared from food items. Such products are proved to be more economical over the liquid products. The products in dry and solid form have less volume thereby easy and cost effective to pack, handle and transport (Sarabandi et al., 2014). Different techniques are in use for the purpose. Candy was prepared from peel by using the method of osmotic dehydration. The research revealed that the peel of the kinnow is a rich source of vitamin C, pectin, limonin and naringin. The purpose of this study was to reduce the waste and to utilize the nutrients present in the peel. The samples were stored in different packaging material and at different temperatures. All the samples placed at refrigeration temperature, showed the microbial count below the limit. The sample of candy placed in HDPE and the powder in laminate bag gave the best results as the these were microbiologically stable (Sidhu et al., 2016). Research was conducted to compare the sensory properties of reconstituted and fresh juice of kinnow. The kinnow powder was prepared by spray drying method. The reconstituted juice was prepared in different dilutions. Malto- dextrin (MD) and sucrose were used as sweeteners while making dilutions. The blend having MD to juice ratio as 35:65 maximum values of correlation coefficient were obtained. for color (0.28), for flavor (0.48) at 35:65, 37.5:62.5 blend, for consistency at (0.24) at 40:60 blend and for overall acceptability (0.48) at 35:65 blend (Dhruv Juyal, 2018). Study was conducted on kinnow fruit dipped in sugar solution and mass transfer kinetics was studied. Whole kinnow fruit was used in this research. The samples were dipped in the sugar solution of 55–75°Brix and exposed to different temperatures treatments (35–65 ℃).

The immersion time of the samples varied from 30 to 270 min. The ratio of solution to fruit was 3–7:1 v/w. Complete randomized design (CRD) was applied to evaluate the data. The parameters like water and mass loss and solute gain were continuously examined. The best results were obtained when 65 ℃ was used as temperature of osmotic process, the sugar solution had the concentration of 65–75°Brix, ratio of solution to fruit was 5:1 and the time of immersion was 270 min. The moisture content and diffusivities of solute were recorded. The research concluded that the important factors effecting the solute gain and water loss were time of immersion and temperature of osmotic process.

The main purpose of this study was to evaluate the best processing conditions for the product prepared from osmotic dehydration. The kinnow slices including the peel were used as sample in this research. The optimal temperature used during the process was (35–75 ℃), concentration of sugar solution was 55–75°Bx and time of immersion was 150–270 min. After the osmotic dehydration, the samples were dried by the use of convective drying. The temperature used for the convective drying was 45–65 ℃. The parameters of osmotic process were assessed by Central Composite Rotatable Design. The best results were obtained at temperature of 65 ℃ for osmotic process, for convective drying temperature was 50 ℃, the concentration of sugar solution was 61°Bx and the time of immersion of samples was about 187 min. physicochemical analysis was done for the samples to be studied (Alam et al., 2019).

The juice was extracted from the kinnow fruit and processed to reduce the bitterness. The sample was prepared by the extraction of juice from the fruit, blanched, centrifuged and absorbents were applied. All the physical and chemical analysis were performed. Reduction in the amounts of naringin and limonin, the major contributors of bitterness, was seen in the results (Kumar et al., 2020).

In the research conducted in 2016, the candy was prepared by using different concentrations of sucrose and fructose from the whole kinnow. The sensory and physicochemical parameters were studied. The samples were treated with calcium hydroxide and dipped in the chemical for nearly 12 hours. The ratios of sucrose and fructose were 100:0, 0:100, 75:25, 50:50, and 25:75, respectively with 70 °Brix of total soluble solids. The samples were studied for a storage period of 4 months. The result revealed that the sample prepared from 100 percent fructose and the sample having 25 % sucrose and 75 % fructose were considered the best organoleptically. Candy prepared with sucrose (100 %) was dull in appearance and crystallization occurred during the storage. The parameters like TSS, total sugars, limonene and reducing sugars were increased while the vitamin c content, moisture and acidity were decreased with passage of time. Ash content had no change during the storage (AggArwAl and MichAel, 2014).

Research on fermented products from kinnow fruit is also in trend. This method showed an increase in the content of carotenoids and flavanone without effecting the amount of vitamin C. Khandelwal et al. (2019) prepared fermented kinnow juice by using the inoculum *Saccharomyces cerevisiae* MTCC 180 (5%). The results of the fermented kinnow juice showed that the TSS of juice was 8.0, pH was 4.41 and total acidity was 0.61. Kinnow juice was also fermented with inoculum of *Saccharomyces cerevisiae* var. ellipsoideus. This was also fermented for 10 days. According to the results the total soluble solids of the juice were 7.99, pH was 3.74 and acidity was 0.86 (Joshi et al., 2012).

Kinnow juice was blended with cane juice and fermented with *Saccharomyces cerevisiae* MTCC 180 (5%) for about 8 days at temperature of 30 ℃.The ratio of kinnow and cane was 80: 20 (Khandelwal et al., 2019). The juice was also blended with the paste of date. The inoculum used for the fermentation of the blend was *Saccharomyces cerevisiae* MTCC- 11815 (Dua and Kocher, 2017).

The peel of the kinnow and the pretreated waste of kinnow were also utilized to prepare the products by fermentation. The duration of fermentation was less as the peel fermented for 5 days and the pretreated waste for only 5 hours. The inoculum used were *Saccharomyces cerevisiae* MTCC 180 7.5% (v/v) and *Saccharomyces cerevisiae*. These products were fermented at temperature of 29 ℃ (Panesar et al., 2009) and 35 ℃ was used for pretreated kinnow waste product development (Babbar et al., 2011).

Different blends are also prepared by mixing the kinnow juice with other fruit juices. Kinnow juice was enriched by blending it with aonla and ginger, as well as with pomegranate juice and ginger juice, aiming to enhance its nutritional and medicinal benefits while improving flavor and palatability. The blend was pasteurized at 75 ℃ for about 15 min and stored at ambient temperature for about six months. Minimum changes were observed in the blend prepared with pomegranate juice and gave better results with respect to sensory evaluation. The results showed that the addition of ginger juice reduced the growth of microbes and the juice was acceptable after the storage (Bhardwaj and Mukherjee, 2011).

Blend was prepared by mixing the kinnow nectar with the aloe juice. The use of aloe vera has been increased due to its health promoting benefits. In this research, the physicochemical analysis of blend was performed during the storage period. The fiber content is higher in aloe juice. It was added in two forms blanched and unblanched. The crude fiber content was higher in the un-blanched sample. Sensory evaluation was done to optimize the ratio of kinnow nectar and aloe juice, 4 % aloe juice gave the better results without effecting the taste of kinnow nectar. (Shubhra et al., 2014).

Best quality kinnow are preferred for the processing purposes but the low grade also poses the bioactive components and can be used to make value added products. Fruit bar was prepared from the kinnow juice that was rich in phytonutrients. The texture and quality of the bar was improved by the addition of pectin (1-4%). Results of analysis showed that the bar contained vitamin C (8.41 mg/100 g), total carotenoids (3.28 mg/100 g), limonin (20 ppm), and antioxidant activity (68.12%). The bars were stored at different temperatures to study the changes on nutritional value. Valorization of low grade kinnow can provide the dual benefit of producing phytonutrient-rich snack product along with kinnow waste management (Aggarwal et al., 2022).

In India, a traditional dessert, Burfi was enriched with the kinnow juice. This was done to make the product healthy as the product was highly consumed. The addition of kinnow juice enhance the Phyto nutritional profile but also improves the shelf life of the product. Product was prepared by using pectin at different concentrations. Pectin not only contributes towards the nutritional profile but also improves the texture. The prepared product was stored at different temperatures but the product showed high sensory acceptability as well as microbial safety up to 21 days at room temperature and 28 days under refrigeration (Kaur et al., 2022).

Infrared technique was used for drying of kinnow peel. The dried peel was added in muffins to enhance its nutritional profile. Ten percent incorporation of kinnow peel dietary fiber resulted in good overall acceptability score (8.00) of muffins which indicates the scope for the utilization of kinnow peel waste as fiber-rich natural food additive in the development of bakery products (Suri et al., 2022).

De-Bittering

The major issue in processing of citrus fruits on industrial scale is its natural bitterness. It results in lowering the quality of the product and also reduces the commercial value of processed products (Puri and Kalra, 2005). All the varieties of juices processed from the citrus fruits contain certain components that are responsible for the bitterness; few contain higher quantities while few contain lesser amount. Such components are usually involved in the defense system of the plants and also prevent herbivory. The majority of citrus cultivars have limonin and naringin both, but have different levels. In processed citrus juices, the naringin and limonin are mainly responsible for causing the bitterness.

The components naringin and limonin are considered responsible for initial and delayed bitterness in citrus fruit juices, respectively. The bitterness caused by naringin is referred as initial bitterness as this component is first to cause bitterness in juices (Puri and Kalra, 2005). This results when the albedo and flavedo part of the fruit membrane becomes the part of juice during extraction. As the juice is extracted from kinnow fruit, it gradually develops bitterness and this is due to the limonin. This is called as delayed bitterness. The enzyme named as limonoate-D-ring lactone hydrolase (LDLH), catalyze the reaction and results in the formation of limonin (Ferreira et al., 2008; Hasegawa and Maier, 1990; Kumar et al., 2020). Flavanone -7-O-neohesperidoside is the component in the naringin which is responsible for imparting bitterness while in case of limonene limonoic-α-ring structure impart bitterness in citrus fruits. Although the bittering is less acceptable but have beneficial effects on health (Xu et al., 2019).

The bittering agent, naringin falls under the category of bioflavonoids. Keeping in view its health benefits, study was done to measure its amount in three different varieties of oranges. Mandarin (*Citrus reticulata*), Kinnow (*Citrus nobilis* × *Citrus deliciosa*), and Nagpur (*Citrus reticulata Blanco*) were selected for the study. HPLC and spectrophotometer were used for the quantification of naringin component. Oranges were blanched repeatedly at 65 °C and then osmotically dehydrated. The naringin loss was monitored during the processing. The samples were stored for the period of six months and loss of naringin was measured. Physicochemical parameters were also assessed during the storage period. Results showed that the blanching had positive effect as the naringin content was reduced to half (50%). During the storage, the naringin was decreased further up to the value of 3–10 mg/100g and this reduction was observed in all the varieties of oranges selected for this research. According to the results obtained from physicochemical analysis, the mandarin variety and kinnow are most adapted for the method of osmotic dehydration (Jagannath and Kumar, 2016).

Due to the lack of cost- effective methods for de-bittering, the farmers and the processing industries face huge economic losses. Research has been done in the past few years to detect and modulate the initial and delayed bitterness in citrus juices. The use of suppressing agents (Shaw and Wilson III, 1985), enzymes (Ferreira et al., 2008; Puri and Kalra, 2005), adsorbents (Singh et al., 1983) are the few methods used for de-bittering of citrus fruit juices including kinnow. Some procedures are not successful, while others are too expensive for industry to implement.

The juice of kinnow mandarin has a pleasant taste and flavor, but naturally occurring limonin (a limonoid) and naringin (a flavonoid) are de-facto bitterness, which leads to the development of chemical elements which adversely affect the acceptance of juices and associated products by the consumer. Different methods are used for the removal of bitterness from the citrus fruits. The use of physical methods for de-bittering is also common in industries. The physical method includes adsorption on activated carbon and resin adsorption (Barmore et al., 1986; Manlan et al., 1990; Puri et al., 1996; Shaw and Buslig, 1986), or enzymatic hydrolysis (Chien et al., 2001; Puri et al., 1996; Soares and Hotchkiss, 1998; TSEN and YU, 1991).

Study was conducted in India for the evaluation of bittering agents (naringin and limonene) present in kinnow and limiting their amounts. The technique used for the quantification of the limonin and naringin was HPLC. Different treatments to juice were applied. The product was evaluated in different durations of harvesting and storage at low and ambient temperatures with different pH values. The juice was blanched, centrifuged and then the absorbents were applied to decrease bitterness. The absorbents used were silica gel, florisil, XAD16, and XAD7 with the control juice sample. The research revealed that if the seeds and peel were removed either manually or mechanically before the extraction of juice, the major reduction in bitterness was observed. Addition of absorbents also exhibited the significant effect against bittering agents further detailing that XAD-7 and XAD-16 gave the best results. Whereas, increased pH and low temperature treatments were effective against bitterness (Kumar et al., 2020).

Bitterness is the major concern in processing of by-products obtained from kinnow. This included the kinnow pulp and pomace. In this research, different methods were applied to reduce the issue and to use the by-products efficiently. The chemical method was applied, where food grade chemicals like solventogenesis (acetone), acid and alkali were applied. According to the research resuts, the solventogenesis showed best results. Maximum amounts of naringin and limonene were removed from the samples by the use of acetone. For the development of food product, this method had shown high acceptability. Response surface methodology was used for the optimization of this method in order to maximize the extraction of limonin and naringin. From the kinnow pomace, the amount of naringin extracted was 8.955 mg/g compared to 2.122 mg/g of limonin. The extracted amounts of naringin and limonin from the pulp was 9.971 and 3.838 mg/g, respectively. This proved to be an effective method to deal with the by-products normally produced by the agro industries. This was also an efficient method in reduction of environmental pollution (Singla et al., 2021).

Further research regarding reduction of the bitterness from the kinnow juice was conducted. Fresh and stored juices were used as samples in the study. Indion NPA1, an adsorbent was selected for the reduction of bitterness from the samples. The main focus of this study was to decrease the naringin content. The kinetic, column and adsorption equilibrium studies were conducted to measure the adsorbed amount of naringin in both fresh as well as stored samples. The adsorbent was also saturated with the citric acid. The amount of dry resin, saturated with citric acid was nearly 1 kg. The amount of naringin adsorbed by the resin from the stored juice was 0.042 and from the fresh juice was 0.043 kg. Initially the amount of naringin in the juices were 0.300(stored) and 0.500(fresh) kg/m3. The major portion of naringin was adsorbed during the initial 30,000 s after this duration the rate of adsorption was reduced. The samples of juices obtained from the column study did not possess the bitter taste. By the use of 1 M NaOH solution, it was possible to regain the used resin around 85- 90 %. This method was an effective method and also the recovery of used resin was possible (Singh et al., 2016b).

Flavonoids, polyphenols, carotenoids, tocopherols, limonoids, etc which exhibit an effective antioxidant capacity are also present in kinnow peel. The issue in processing is bitterness present in peel and naringin is the most predominant compound that causes bitterness. Ultrasound-assisted microbial debittering was utilized for hydrolysis of naringin content and this reduced processing time. The optimum conditions (temperature (40 °C), time (30 min), and *A. niger* koji extract (1.45%) were used for the maximum extraction of naringin (11.91 mg/g). Peels de-bittered by this method can be utilized as raw material to develop therapeutic food products having a high phytochemical composition without any off-flavors or bitterness (Suri et al., 2022).

CONCLUSIONS

The Kinnow fruit is preferred over other citrus fruit as whole fruit and mainly for its juice and juice-based products. The acceptability is because of its nutritional status, aroma and fiber content. Various value-added products are in market. bitterness is the limiting factor in juice extraction, processing and preservation. Debittering techniques and treatments can effectively be used. Thereby increase in the variety of kinnow juice-based products can be obtained. This can lead to achieve sustainable economic goals by preserving the fruit juice.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

REFERENCES

Abeysinghe, D., Li, X., Sun, C., Zhang, W., Zhou, C., Chen, K., 2007. Bioactive compounds and antioxidant capacities in different edible tissues of citrus fruit of four species. Food Chemistry 104, 1338-1344.

Additives, E.P.o., Feed, P.o.S.u.i.A., 2011. Scientific Opinion on the safety and efficacy of naringin when used as a sensory additive for all animal species. EFSA Journal 9, 2416.

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.

AggArwAl, P., MichAel, M., 2014. Effect of replacing sucrose with fructose on the physico-chemical sensory characteristics of kinnow candy. Czech Journal of Food Sciences 32, 158-163.

Ahmed, U.I., Ying, L., Mushtaq, K., Bashir, M.K., 2015. An econometric estimation of post-harvest losses of kinnow in Pakistan. International Journal of Economics, Commerce and Management 3, 373-383.

Alam, M., Kaur, M., Ramya, H., 2019. Efficacy of osmo-convective process parameters for Kinnow fruit slices and its optimization using response surface methodology. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 89, 605-614.

Ali, M.A., Zulfiqar, A., Arif, A.M., Khan, A.-R., Iqbal, Z., Khan, M.A., 2015. Effect of natural and synthetic fruit coatings on the postharvest quality of kinnow mandarins. Agricultural Engineering International: CIGR Journal 17.

Anderson, J.W., Baird, P., Davis Jr, R.H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., Williams, C.L., 2009. Health benefits of dietary fiber. Nutrition Reviews 67, 188-205.

Anticona, M., Blesa, J., Lopez-Malo, D., Frigola, A., Esteve, M.J., 2021. Effects of ultrasound-assisted extraction on physicochemical properties, bioactive compounds, and antioxidant capacity for the valorization of hybrid Mandarin peels. Food Bioscience 42, 101185.

Aulakh, P.S., Thind, S.K., Arora, P.K., 2008. Kinnow. Punjab Agricultural University, Ludhiana, 48.

Babbar, N., Oberoi, H.S., Sandhu, S.K., 2015. Therapeutic and nutraceutical potential of bioactive compounds extracted from fruit residues. Critical Reviews in Food Science and Nutrition 55, 319-337.

Babbar, N., Oberoi, H.S., Uppal, D.S., Patil, R.T., 2011. Total phenolic content and antioxidant capacity of extracts obtained from six important fruit residues. Food Research International 44, 391-396.

Baghkhandan, M.S., 2006. 10. ISLAMIC REPUBLIC OF IRAN (2) Postharvest management of fruit and vegetables in the Asia-Pacific region.

Baghurst, K., 2003. The health benefits of citrus fruits. Horticulture Australia, Sydney.

Bajwa, B.E., Anjum, F.M., 2007. Improving storage performance of Citrus reticulata Blanco mandarins by controlling some physiological disorders. International Journal of Food Science & Technology 42, 495-501.

Barmore, C.R., Fisher, J.F., FELLERS, P.J., Rouseff, R.L., 1986. Reduction of bitterness and tartness in grapefruit juice with Florisil. Journal of Food Science 51, 415-416.

Ben-Yehoshua, S., Rodov, V., Fang, D.Q., Kim, J.J., 1995. Preformed antifungal compounds of citrus fruit: effect of postharvest treatments with heat and growth regulators. Journal of Agricultural and Food Chemistry 43, 1062-1066.

Bezman, Y., Rouseff, R.L., Naim, M., 2001. 2-Methyl-3-furanthiol and methional are possible off-flavors in stored orange juice: aroma-similarity, NIF/SNIF GC− O, and GC analyses. Journal of Agricultural and Food Chemistry 49, 5425-5432.

Bhardwaj, R., Mukherjee, S., 2011. Effects of fruit juice blending ratios on kinnow juice preservation at ambient storage condition. African Journal of Food Science 5, 281-286.

Bhardwaj, R., Nandal, U., 2014. Effect of storage temperature on physico-chemical and sensory evaluation of kinnow mandarin juice blends. Journal of Food Processing & Technology 5, 1-4.

Bocco, A., Cuvelier, M.-E., Richard, H., Berset, C., 1998. Antioxidant activity and phenolic composition of citrus peel and seed extracts. Journal of Agricultural and Food Chemistry 46, 2123-2129.

Bok, S.-H., Lee, S.-H., Park, Y.-B., Bae, K.-H., Son, K.-H., Jeong, T.-S., Choi, M.-S., 1999. Plasma and hepatic cholesterol and hepatic activities of 3-hydroxy-3-methyl-glutaryl-CoA reductase and acyl CoA: cholesterol transferase are lower in rats fed citrus peel extract or a mixture of citrus bioflavonoids. The Journal of Nutrition 129, 1182-1185.

Bronner, W., Beecher, G., 1995. Extraction and measurement of prominent flavonoids in orange and grapefruit juice concentrates. Journal of Chromatography A 705, 247-256.

Buscemi, S., Corleo, D., Di Pace, F., Petroni, M.L., Satriano, A., Marchesini, G., 2018. The effect of lutein on eye and extra-eye health. Nutrients 10, 1321.

Caro, A.A., Cederbaum, A.I., 2004. Oxidative stress, toxicology, and pharmacology of CYP2E1. Annual Review of Pharmacology and Toxicology 44, 27-42.

Castro-Vazquez, L., Alañón, M.E., Rodríguez-Robledo, V., Pérez-Coello, M.S., Hermosín-Gutierrez, I., Díaz-Maroto, M.C., Jordán, J., Galindo, M.F., Arroyo-Jimenez, M.d.M., 2016. Bioactive flavonoids, antioxidant behaviour, and cytoprotective effects of dried grapefruit peels (Citrus paradisi Macf.). Oxidative Medicine and Cellular Longevity 2016, 8915729.

Chien, P.J., Sheu, F., Shyu, Y.T., 2001. Monitoring enzymatic debittering in grapefruit juice by high performance liquid chromatography. Journal of Food and Drug Analysis 9, 8.

Cho, K.S., Lim, Y.-r., Lee, K., Lee, J., Lee, J.H., Lee, I.-S., 2017. Terpenes from forests and human health. Toxicological Research 33, 97-106.

Choi, M.-S., Do, K.-M., Park, Y.B., Jeon, S.-M., Jeong, T.-S., Lee, Y.-K., Lee, M.-K., Bok, S.-H., 2001. Effect of naringin supplementation on cholesterol metabolism and antioxidant status in rats fed high cholesterol with different levels of vitamin E. Annals of Nutrition and Metabolism 45, 193-201.

CM, W., 2013. Potassium and health. Advance Nutrition 4, 368–377.

Cory, H., Passarelli, S., Szeto, J., Tamez, M., Mattei, J., 2018. The role of polyphenols in human health and food systems: A mini-review. Frontiers in Nutrition 5, 370438.
Craig, W.J., 1997. Phytochemicals: guardians of our health. Journal of the American Dietetic Association 97, S199-S204.
Deshmukh, N., Patel, R., Rymbai, H., Jha, A., Deka, B.C., 2016. Fruit maturity and associated changes in Khasi mandarin (*Citrus reticulata*) at different altitudes in humid tropical climate. Indian Journal of Agricultural Sciences 86, 854-859.
Devaki, S.J., Raveendran, R.L., 2017. Vitamin C: sources, functions, sensing and analysis, Vitamin C. IntechOpen.
Devasagayam, T., Tilak, J., Boloor, K., Sane, K.S., Ghaskadbi, S.S., Lele, R., 2004. Free radicals and antioxidants in human health: current status and future prospects. Japi 52, 4.
Dhall, R., 2013. Advances in edible coatings for fresh fruits and vegetables: a review. Critical Reviews in Food Science and Nutrition 53, 435-450.
Dhruv Juyal, D.J., 2018. Sensory evaluation of kinnow powder. International Journal of Agricultural Engineering 11, 90-94.
Dillard, C.J., German, J.B., 2000. Phytochemicals: nutraceuticals and human health. Journal of the Science of Food and Agriculture 80, 1744-1756.
Dua, K., Kocher, G.S., 2017. Fermentative processing of kinnow juice and extraction of limonin from kinnow waste. Current Trends in Biomedical Engineering & Biosciences 4, 555637.
Elvira-Torales, L.I., García-Alonso, J., Periago-Castón, M.J., 2019. Nutritional importance of carotenoids and their effect on liver health: A review. Antioxidants 8, 229.
Fanciullino, A.-L., Dhuique-Mayer, C., Luro, F., Casanova, J., Morillon, R., Ollitrault, P., 2006. Carotenoid diversity in cultivated citrus is highly influenced by genetic factors. Journal of Agricultural and Food Chemistry 54, 4397-4406.
Ferreira, L., Afonso, C., Vila-Real, H., Alfaia, A., Ribeiro, M.H., 2008. Evaluation of the effect of high pressure on naringin hydrolysis in grapefruit juice with naringinase immobilised in calcium alginate beads. Food Technology and Biotechnology 46, 146.
Finglas, P.M., Berry, R., Astley, S., 2014. Assessing and improving the quality of food composition databases for nutrition and health applications in Europe: the contribution of EuroFIR. Advances in Nutrition 5, 608S-614S.
Giannuzzo, A.N., Boggetti, H.J., Nazareno, M.A., Mishima, H.T., 2003. Supercritical fluid extraction of naringin from the peel of Citrus paradisi. Phytochemical Analysis 14, 221-223.
Gorinstein, S., Cvikrova, M., Machackova, I., Haruenkit, R., Park, Y.-S., Jung, S.-T., Yamamoto, K., Ayala, A.L.M., Katrich, E., Trakhtenberg, S., 2004. Characterization of antioxidant compounds in Jaffa sweeties and white grapefruits. Food Chemistry 84, 503-510.
Grosso, G., Bei, R., Mistretta, A., Marventano, S., Calabrese, G., Masuelli, L., Giganti, M.G., Modesti, A., Galvano, F., Gazzolo, D., 2013. Effects of vitamin C on health: a review of evidence. Front Biosci (Landmark Ed) 18, 1017-1029.
Hasegawa, S., Maier, V., 1990. Biochemistry of limonoid citrus juice bitter principles and biochemical debittering processes. Developments in Food Science 25, 281-287.
He, F.J., MacGregor, G.A., 2008. Beneficial effects of potassium on human health. Physiologia plantarum 133, 725-735.
Hossain, M., 2015. An overview on post harvest handling and commercial processing of horticultural crops in NEH region of India. International Journal of Science and Research 4, 2304-2308.
Ignat, I., Volf, I., Popa, V.I., 2011. A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables. Food Chemistry 126, 1821-1835.
Izquierdo, L., Sendra, J., 2003. Citrus fruits: composition and characterization.
Jagannath, A., Kumar, M., 2016. Monitoring blanching induced debittering and storage losses of naringin in orange subjected to osmotic dehydration. International Journal of Fruit Science 16, 410-422.
Jiao, Y., Reuss, L., Wang, Y., 2019. β-Cryptoxanthin: Chemistry, occurrence, and potential health benefits. Current Pharmacology Reports 5, 20-34.
Joshi, V., Kumar, V., Kumar, A., 2012. Physico-chemical and sensory evaluation of wines from different citrus fruits of Himachal Pradesh. International Journal of Food and Fermentation Technology 2, 145-148.
Joshi, V., Thakur, N., Lal Kaushal, B., 1997. Effect of debittering of kinnow juice on physico-chemical and sensory quality of kinnow wine. INDIAN FARMING-DELHI-US JAIN- 51, 5-10.
Joshipura, K.J., Hu, F.B., Manson, J.E., Stampfer, M.J., Rimm, E.B., Speizer, F.E., Colditz, G., Ascherio, A., Rosner, B., Spiegelman, D., 2001. The effect of fruit and vegetable intake on risk for coronary heart disease. Annals of Internal Medicine 134, 1106-1114.
Jung, U.J., Choi, M.-S., Lee, M.-K., Jeong, K.-S., 2004. The hypoglycemic effects of hesperidin and naringin are partly mediated by hepatic glucose-regulating enzymes in C57BL/KsJ-db/db mice. The Journal of Nutrition 134, 2499-2503.
Kanaze, F.I., Gabrieli, C., Kokkalou, E., Georgarakis, M., Niopas, I., 2003. Simultaneous reversed-phase high-

performance liquid chromatographic method for the determination of diosmin, hesperidin and naringin in different citrus fruit juices and pharmaceutical formulations. Journal of Pharmaceutical and Biomedical Analysis 33, 243-249.

Kandi, S., Godishala, V., Rao, P., Ramana, K., 2015. Biomedical significance of terpenes: an insight. Biomedicine 3, 8-10.

Kashyap, K., Banu, S., 2019. Characterizing ethylene pathway genes during the development, ripening, and postharvest response in *Citrus reticulata* Blanco fruit pulp. Turkish Journal of Botany 43, 173-184.

Kashyap, K., Kashyap, D., Nitin, M., Ramchiary, N., Banu, S., 2020. Characterizing the nutrient composition, physiological maturity, and effect of cold storage in Khasi mandarin (*Citrus reticulata* Blanco). International Journal of Fruit Science 20, 521-540.

Kaur, S., Aggarwal, P., Kaur, N., 2022. Enhanced functionality and shelf stability of burfi by incorporating kinnow (mandarin) fruit juice. Journal of Food Science and Technology 59, 4956-4968.

Kawaii, S., Tomono, Y., Katase, E., Ogawa, K., Yano, M., 1999. Quantitation of flavonoid constituents in citrus fruits. Journal of Agricultural and Food Chemistry 47, 3565-3571.

Khalid, S., 2013. Fruit quality and storability of Kinnow mandarin (Citrus reticulata Blanco) in relation to tree age. University of Agriculture Faisalabad Punjab, Pakistan.

Khandelwal, S., Verma, G., Shaikh, N.I., Siegel, K.R., Soni, D., Soni, D., Thow, A.-M., 2019. Mapping of policies related to fruits and vegetables accessibility in India. Journal of Hunger & Environmental Nutrition.

Knekt, P., Kumpulainen, J., Järvinen, R., Rissanen, H., Heliövaara, M., Reunanen, A., Hakulinen, T., Aromaa, A., 2002. Flavonoid intake and risk of chronic diseases. The American Journal of Clinical Nutrition 76, 560-568.

Knekt, P., Ritz, J., Pereira, M.A., O'Reilly, E.J., Augustsson, K., Fraser, G.E., Goldbourt, U., Heitmann, B.L., Hallmans, G., Liu, S., 2004. Antioxidant vitamins and coronary heart disease risk: a pooled analysis of 9 cohorts. The American Journal of Clinical Nutrition 80, 1508-1520.

Kumar, S., Kumar, R., Sharma, P., 2020. De-bittering studies of kinnow mandarin (*Citrus reticulata* Blanco) juice. Journal of Environmental Biology 41, 1068-1074.

Lado, J., Rodrigo, M.J., Zacarías, L., 2014. Maturity indicators and citrus fruit quality. Stewart Postharvest Review 10, 1-6.

Li, N., Xu, Z., Wooley, P.H., Zhang, J., Yang, S.-Y., 2014. Therapeutic potentials of naringin on polymethylmethacrylate induced osteoclastogenesis and osteolysis, in vitro and in vivo assessments. Drug Design, Development and Therapy, 1-11.

Li, Y.O., Komarek, A.R., 2017. Dietary fibre basics: Health, nutrition, analysis, and applications. Food Quality and Safety 1, 47-59.

Liu, R.H., 2003. Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. The American Journal of Clinical Nutrition 78, 517S-520S.

Liu, R.H., 2004. Potential synergy of phytochemicals in cancer prevention: mechanism of action. The Journal of Nutrition 134, 3479S-3485S.

Mahawar, M.K., Jalgaonkar, K., Bibwe, B., Bhushan, B., Meena, V.S., Sonkar, R.K., 2020. Post-harvest processing and valorization of Kinnow mandarin (*Citrus reticulate* L.): A review. Journal of Food Science and Technology 57, 799-815.

Manlan, M., Matthews, R., Rouseff, R., Littell, R., Marshall, M., Moye, H., Teixeira, A., 1990. Evaluation of the properties of polystyrene divinylbenzene adsorbents for debittering grapefruit juice. Journal of Food Science 55, 440-445.

Mann, S., Aggarwal, K., 2013. Development of phytochemical rich ice cream incorporating kinnow peel. Global Journal of Science Frontier Research 13, 1-3.

Manthey, J.A., Grohmann, K., 2001. Phenols in citrus peel byproducts. Concentrations of hydroxycinnamates and polymethoxylated flavones in citrus peel molasses. Journal of Agricultural and Food Chemistry 49, 3268-3273.

Mathur, A., Verma, S.K., Purohit, R., Gupta, V., Dua, V., Prasad, G., Mathur, D., Singh, S.K., Singh, S., 2011. Evaluation of in vitro antimicrobial and antioxidant activities of peel and pulp of some citrus fruits. Journal of Biotechnology and Biotherapeutics 1, 1-17.

Middleton, E., 1994. Potential health-promoting properties of citrus flavonoids. Food Technology 48, 115-119.

Miri, S.M., Salari, M., Ahmadpour, A., 2017. Determining appropriate harvesting date and storage life of Kinnow mandarine fruits in Jiroft county. Journal of Horticultural Science 31, 483-491.

Miri, S.M., Salari, M., Ahmadpour, A., 2018. Physicochemical responses of 'Kinnow'mandarins to wax and polyethylene covering during cold storage. Open Agriculture 3, 678-683.

Mollapur, Y., Miri, S.M., Hadavi, E., 2016. Comparison of foliar fertilizers and growth regulators on pre-harvest drop and fruit quality of 'Thompson Navel'orange. Open Agriculture 1, 112-117.

Nagy, S., 1980. Vitamin C contents of citrus fruit and their products: a review. Journal of Agricultural and Food Chemistry 28, 8-18.

Nath, A., Barman, K., Chandra, S., Baiswar, P., 2013. Effect of plant extracts on quality of Khasi mandarin (*Citrus reticulata* Blanco) fruits during ambient storage. Food and Bioprocess Technology 6, 470-474.

Okwu, D.E., 2008. Citrus fruits: A rich source of phytochemicals and their roles in human health. International Journal of Chemical Sciences 6, 451-471.

Panesar, P.S., Panesar, R., Singh, B., 2009. Application of response surface methodology in the optimization of process parameters for the production of kinnow wine. Agricultural and Food Sciences, Chemistry.

Petracek, P.D., Davis, C., 1996. Effects of selected preharvest factors on postharvest pitting of white grapefruit, Proceedings of the Florida State Horticultural Society, pp. 251-253.

Premi, B., Lal, B., Joshi, V., 1994. Distribution pattern of bittering principles in Kinnow fruit.

Puri, M., Kalra, S., 2005. Purification and characterization of naringinase from a newly isolated strain of *Aspergillus niger* 1344 for the transformation of flavonoids. World Journal of Microbiology and Biotechnology 21, 753-758.

Puri, M., Marwaha, S., Kothari, R., 1996. Studies on the applicability of alginate-entrapped naringiase for the debittering of kinnow juice. Enzyme and Microbial Technology 18, 281-285.

Putnik, P., Barba, F.J., Lorenzo, J.M., Gabrić, D., Shpigelman, A., Cravotto, G., Bursać Kovačević, D., 2017. An integrated approach to mandarin processing: Food safety and nutritional quality, consumer preference, and nutrient bioaccessibility. Comprehensive Reviews in Food Science and Food Safety 16, 1345-1358.

Rattanpal, H., Singh, G., Singh, S., Arora, A., 2017. Citrus cultivation in Punjab. Punjab Agricultural University, Ludhiana, India 10.

Rehman, S.U., Abbasi, K.S., Qayyum, A., Jahangir, M., Sohail, A., Nisa, S., Tareen, M.N., Tareen, M.J., Sopade, P., 2019. Comparative analysis of citrus fruits for nutraceutical properties. Food Science and Technology 40, 153-157.

Rokaya, P.R., Baral, D.R., Gautam, D.M., Shrestha, A.K., Paudyal, K.P., 2016. Effect of pre-harvest application of gibberellic acid on fruit quality and shelf life of mandarin (*Citrus reticulata* Blanco). American Journal of Plant Sciences 7, 1033.

Ross, S.A., Ziska, D.S., Zhao, K., ElSohly, M.A., 2000. Variance of common flavonoids by brand of grapefruit juice. Fitoterapia 71, 154-161.

Sarabandi, K., Peighambardoust, S.H., Shirmohammadi, M., 2014. Physical properties of spray dried grape syrup as affected by drying temperature and drying aids. International Journal of Agriculture and Crop Sciences 7, 928.

Sharma, N., Kalra, K., Oberoi, H.S., Bansal, S., 2007. Optimization of fermentation parameters for production of ethanol from kinnow waste and banana peels by simultaneous saccharification and fermentation. Indian Journal of Microbiology 47, 310-316.

Shaw, P.E., Buslig, B.S., 1986. Selective removal of bitter compounds from grapefruit juice and from aqueous solution with cyclodextrin polymers and with Amberlite XAD-4. Journal of Agricultural and Food Chemistry 34, 837-840.

Shaw, P.E., Wilson III, C.W., 1985. Reduction of Bitterness in Grapefruit Juice with β-Cyclodextrin Polymer in a Continuous-Flow Process. Journal of Food Science 50, 1205-1207.

Shubhra, B., Swati, K., Singh, R.P., Savita, S., 2014. Studies on aloe juice supplemented kinnow nectar. Research Journal of Agriculture and Forestry Sciences 2320, 6063.

Sidhu, N., Arora, M., Alam, M.S., 2016. Biochemical, microbial stability and sensory evaluation of osmotically dehydrated kinnow peel candy and peel powder. International Journal of Science and Research 5, 1428-1436.

Singh, A.K., Meetei, N.T., Singh, B.K., Mandal, N., 2016a. Khasi mandarin: its importance, problems and prospects of cultivation in North-eastern Himalayan region. International Journal of Agriculture, Environment and Biotechnology 9, 573-592.

Singh, S.V., Jain, R., Gupta, A., 2016b. Adsorptive reduction of naringin from kinnow mandarin juice with non-ionic macroporous adsorbent resin. Indian Chemical Engineer 58, 136-156.

Singh, U., Wadhwani, A.M., Johri, B.M., 1983. Dictionary of economic plants in India, 2nd edn. Indian Council of Agricultural Research (ICAR), New Delhi, pp 51–53.

Singla, G., Singh, U., Sangwan, R.S., Panesar, P.S., Krishania, M., 2021. Comparative study of various processes used for removal of bitterness from kinnow pomace and kinnow pulp residue. Food Chemistry 335, 127643.

Singla, R., Rattanpal, H., Singh, G., 2018. Storage performance of hot water treated Kinnow fruits under ambient conditions. International Journal of Current Microbiology and Applied Sciences 7, 3775-3782.

Soares, N., Hotchkiss, J., 1998. Naringinase immobilization in packaging films for reducing naringin concentration in grapefruit juice. Journal of Food Science 63, 61-65.

Suri, S., Singh, A., Nema, P.K., Taneja, N.K., 2022. A comparative study on the debittering of Kinnow (*Citrus reticulate* L.) peels: microbial, chemical, and ultrasound-assisted microbial treatment. Fermentation 8, 389.

TANIZAWA, H., OHKAWA, Y., TAKINO, Y., MIYASE, T., UENO, A., KAGEYAMA, T., HARA, S., 1992. Studies on natural antioxidants in citrus species. I. Determination of antioxidative activities of citrus fruits. Chemical and Pharmaceutical Bulletin 40, 1940-1942.

Tanwar, B., Modgil, R., 2012. Flavonoids: Dietary occurrence and health benefits. Spatula Dd 2, 59-68.

Temple, N.J., 2000. Antioxidants and disease: more questions than answers. Nutrition Research 20, 449-459.

Tietel, Z., Lewinsohn, E., Fallik, E., Porat, R., 2012. Importance of storage temperatures in maintaining flavor and quality of mandarins. Postharvest Biology and Technology 64, 175-182.

TSEN, H.Y., YU, G.K., 1991. Limonin and naringin removal from grapefruit juice with naringinase entrapped in cellulose triacetate fibers. Journal of Food Science 56, 31-34.

Ullah, N., Qazi, I.M., Masroor, S., Ali, I., Khan, A., Khan, M., Gillani, A., 2015. Preservation of ready to serve blended carrot and kinnow (mandarin) drink by ginger extract. Journal of Food Processing & Technology 6, 1.

Wang, L., Wang, J., Fang, L., Zheng, Z., Zhi, D., Wang, S., Li, S., Ho, C.-T., Zhao, H., 2014. Anticancer activities of citrus peel polymethoxyflavones related to angiogenesis and others. BioMed Research International 2014, 453972.

Wei, M., Yang, Z., Li, P., Zhang, Y., Sse, W.C., 2007. Anti-osteoporosis activity of naringin in the retinoic acid-induced osteoporosis model. The American Journal of Chinese Medicine 35, 663-667.

Willett, W.C., 2002. Balancing life-style and genomics research for disease prevention. Science 296, 695-698.

Xu, M., Ran, L., Chen, N., Fan, X., Ren, D., Yi, L., 2019. Polarity-dependent extraction of flavonoids from citrus peel waste using a tailor-made deep eutectic solvent. Food Chemistry 297, 124970.

Yadav, A., Kumari, R., Yadav, A., Mishra, J., Srivatva, S., Prabha, S., 2016. Antioxidants and its functions in human body-A Review. Research in Environment and Life Sciences 9, 1328-1331.

Yao, L.H., Jiang, Y.-M., Shi, J., Tomas-Barberan, F., Datta, N., Singanusong, R., Chen, S., 2004. Flavonoids in food and their health benefits. Plant Foods for Human Nutrition 59, 113-122.

Yaqoob, M., Kaur, M., Aggarwal, P., Ahluwalia, P., 2020. Kinnow. Antioxidants in Fruits: Properties and Health Benefits, 417-433.

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