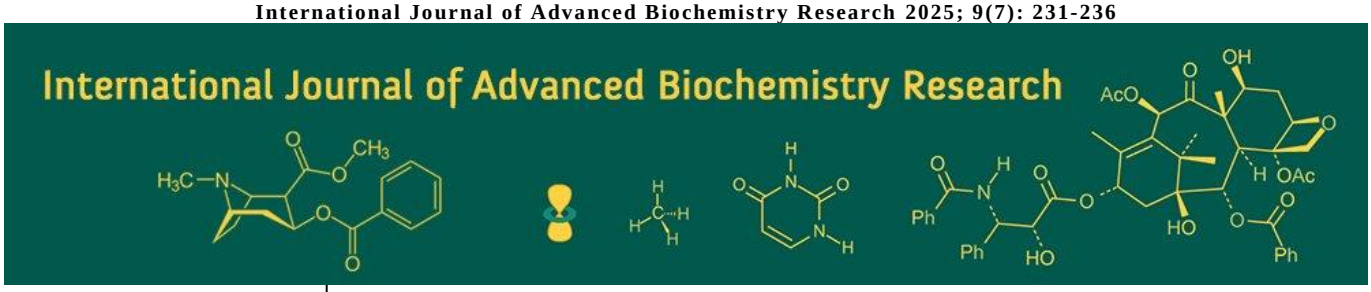

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Assam lemon (*Citrus limon* L. Burm. f.): A comprehensive review of nutritional composition, phytochemical properties, and health benefits

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Abstract
Assam lemon (*Citrus limon* L. Burm. f.), locally known as "Kaji Nemu, " is a distinctive citrus variety native to northeastern India, prized for its unique aroma, seedlessness, and high juice content. This review explores its nutritional profile, phytochemical properties, and potential health benefits. Assam lemon is rich in bioactive compounds such as vitamin C, citric acid, flavonoids, pectin, and essential oils—particularly limonene—which contribute to its antioxidant, antimicrobial, and therapeutic effects. These attributes make it suitable for applications in the food, pharmaceutical, and cosmetic industries. Physicochemical characteristics like juice content, fruit weight, TSS, and acidity vary across maturity stages and growing regions, influencing quality and market value. Essential oil extracted from the peel has shown diverse medicinal uses, while pectin is in high demand as a gelling and stabilizing agent. Despite its nutritional and industrial significance, the fruit is prone to postharvest losses due to microbial spoilage and moisture loss. Current preservation techniques, including edible coatings and modified atmosphere packaging, aim to extend shelf life while reducing reliance on chemical treatments. Moreover, understanding soil interactions and promoting value-added products can enhance sustainable production. This review highlights the multifaceted value of Assam lemon and emphasizes the need for further research to harness its full potential as a functional food and industrial crop.

Keywords: Assam lemon, *Citrus limon*, phytochemical properties, nutritional composition, essential oils, pectin, functional food, postharvest preservation

1. Introduction
According to the Indian Council of Agricultural Research's 1956 monograph, Classification of Citrus Fruits of Assam, it was further propagated vegetatively to maintain its distinctive non-seediness and became a clonal horticultural cultivar known as Assam lemon (Bhattacharya and Dutta 1956) [11]. Lemons come in a variety of forms that may differ somewhat from one another. It is one of the most promising fruit crops in the world because of its broad adaptability. The Assam Lemon, a dwarf cultivar that is ideal for high density planting, is a significant lemon variety that is extensively grown in northeastern India (Singh and Singh 2006) [58].

1.1 Importance and uniqueness of Assam Lemon (regional identity
Assam lemon is well-known for its unique flavour and scent, and it has become more and more popular in both home and foreign markets (Ahmed, R. *et al*. 2023) [2]. With over 15, 000 hectares of farmed land and an annual production of about 1.56 lakh metric tons, Assam lemon has earned a prestigious position as the state's second most popular citrus type (anonymous 2022) [4]. Assam's economy is based primarily on agriculture, which plays an essential and indispensable role. More than 70% of the people in the state make their living from agricultural work. One exceptional quality of Assam is its ability to grow almost any kind of fruit or vegetable (Deka *et al*. 2020) [15]. The most significant lemon variety in Assam and other parts of Northeast India is the Assam lemon. In Assam, it is referred to as "Kazi Nemu, " in Western India, as "Pat Nimboo, " and in Andhra Pradesh, as "Seville lemon" (Chattopadhyay 2007) [13].

1.2 Chronological Development of Assam Lemon Research

The Assam lemon (*Citrus limon* Burm. f.), locally known as 'Kaji Nemu', was first identified in the 1940s at the Government Citrus Fruit Research Station, Byrnihat, Meghalaya Bhattacharyya and Dutta (1956) [11]. It originated from a chance seedling of the China-kaghi variety collected from Hahchora village in Sivasagar district, Assam Thakur S (2010) [63]. Its seedless nature and aromatic profile led to its propagation as a clonal horticultural cultivar Handique *et al*. (2022) [26].

Fruit development studies showed that Assam lemon matures around 150 days after fruit set, with peak juice content and acidity at this stage (Kalita *et al*., 1995) [33]. As the fruit ripens, ascorbic acid and sugar levels decline while pectin content increases, improving processing suitability (Nath and Sarma, 1993) [44]. These physiological insights are essential for determining optimal harvest timing and enhancing shelf stability in RTS beverages (Langthasa & Bhattacharyya, 1991) [38].

Genetic profiling using ISSR markers revealed 85.08% polymorphism among 510 samples from 97 locations across Assam, indicating significant genetic differentiat *et al*., 2023) [3]. Populations from Tinsukia and Dhemaji districts showed close resemblance to the original stock conserved at Kahikuchi Akhtar *et al*. (2024) [4]. These findings support the hypothesis of both clonal propagation and natural hybridization Salonia *et al*. (2020) [51].

Agronomic trials between 2013 and 2015 demonstrated that integrated nutrient management—combining organic, inorganic, and biofertilizers—enhanced fruit weight, juice content, and TSS levels (Ghosh *et al*., 2017) [22]. These practices contributed to sustainable farming and improved fruit quality (Hazarika & Aheibam, 2019) [28]. Additional studies confirmed the role of pruning and soil nutrient availability in optimizing lemon productivity (Coimbra *et al*., 2018) [14].

Morphological studies across 22 districts highlighted variability in fruit shape, seed count, and biochemical traits such as citric acid and pectin content. Seedlessness was predominantly observed in Upper Assam regions, especially Dhemaji and Tinsukia (Akhtar *et al*., 2024) [4]. Biochemical analyses revealed significant variation in ascorbic acid and pectin levels, which are crucial for nutritional and industrial applications (Kalita *et al*., 1995; Singhal *et al*., 2024) [33, 59].

2. Nutritive value and its potential

Assam is part of the world's citrus belt. Because of their high nutritional content, citrus fruits are much sought after. They are rich in vital nutrients such vitamins A and B, natural carbohydrates, and vitamin C (ascorbic acid) (Kumar and Sharma 2019) [53].

2.1 Nutrition Value

Citrus fruits, which are also excellent sources of citric acid, flavonoids, phenolic, pectin, limonoids, ascorbic acids, and other nutrients, are widely known for their dietary, nutritional, therapeutic, and cosmetic qualities (Dugo and Giacomo 2002, Kumar *et al*. 2010) [18, 37]. According to recent studies, Assam lemons are rich in a number of significant chemicals, such as citric acid, ascorbic acid, pectin, flavonoids, and others, which support their antioxidant qualities and other medicinal qualities (Gogoi M 2017, Khatiwora *et al*. 2017) [23, 36]. It is well known that citrus peels contain important substances like EO and pectin, the latter of which gives the fruit its structural integrity and natural defenses. EO includes a wide range of volatile compounds, including oxygenated byproducts such alcohols, esters, terpenes, and citral aldehydes. These active compounds give EOs their scent and have a variety of uses in the pharmaceutical sector, food additives and flavoring, personal care products, and as natural antimicrobials (Putnik *et al*. 2017, Tiwari *et al*. 2017) [49, 65]. Numerous other essential elements, such as phosphorus, calcium, potassium, iron, sodium, sulfur, vitamin B1, and folic acid, are also present in citrus fruits. Citrus's distinct flavor is accentuated by the endocarp region's soluble sugar, pectin, vitamin C, fibers, potassium salt, and organic acids (Morgan and Connolly 2013) [41].

2.2 Potential of Assam Lemon

Additionally, because of its nutritional importance, it is a source for cosmetic and pharmaceutical products (Barua and Bharadwaj 2017) [8]. Assam lemon, a significant variety of *C. limon*, is one of these and is farmed extensively in Assam (Sheikh *et al*. 2021) [55]. The nutritional value and potential health advantages of Assam lemon are known to be significantly influenced by its biochemical makeup, in addition to morphological and seeding differences (Samtiya *et al*. 2021) [52]. Investigating the biochemical changes in Assam lemon throughout different districts of Assam is likely to provide significant information for understanding the potential of distinct populations for applications in functional foods, nutraceuticals, and pharmaceutical sector (Hsouna *et al*. 2023, Ye 2018) [30, 69]. The Rutaceae family includes the Assam lemon (Citrus limon Burm.), a citrus species with a variety of culinary and therapeutic applications and significant economic significance. It is an Assamese native variety. After orange and mandarin, lemon is the third most significant citrus species (Porat *et al*. 2000) [46]. Pectin is in high demand in the food, pharmaceutical, and cosmetic industries because it performs a number of vital tasks as an emulsifier, gelling agent, glazing agent, stabilizer, and thickening (Tuan *et al*. 2019) [66].

3. Physico-Chemical

In this case study (Mukhim, C 2010) [42], the physicochemical characteristics of Assam lemons at various phases of fruit growth and development were examined in an experiment conducted in the mid-hills of Meghalaya, India. Fruits harvested 120 to 130 days after fruit set developed acceptable physico-chemical qualities, including optimum fruit weight (109.28 to 112.95 g), fruit size (Length = ≥ 81.05 mm, Breadth = ≥ 50.13 mm), specific gravity (0.97 to 1.01), juice content (37.68 to 41.23%), TSS (≥6.3 °Brix), titratable acidity (4.18 to 4.35%), ascorbic acid (≥32.41 mg/100 g), and TSS: acidity (≥1.51). These may be the most reliable maturity indices for making harvest decisions in Assam lemon fruit.

4. Parameters

The pH 700 m (Eutech Instruments, United Kingdom) was used to measure the overall pH of the Assam lemon juice (Reddy *et al*. 2016) [50]. With the use of an OPTi digital refractometer (Bellingham + Stanley, UK), the total soluble solids of the lemon juice were calculated as Brix (Uresti-Porras *et al*. 2021) [67]. With minor adjustments, the methodology outlined by Kashyap *et al*. in 2020 was used to

determine the percentage of juice content (Kashyap *et al*. 2020) [34]. The assessment of citric acid concentration in the juice of Assam lemon fruits was done using a modified procedure described by (Brima *et al*. 2014) [12]. Using a modified procedure outlined, the ascorbic acid concentration of Assam lemon fruit juice was determined (Satpathy *et al*. 2021) [54]. In accordance with the modified procedure outlined 3, 5-dinitro salicylic acid (DNS) was used to quantify reducing sugar (Gusakov *et al*., 2011) [25]. With a few minor adjustments, the procedure was followed to determine the equivalent weight content in the peel and pulp samples of Assam lemons (Khamsucharit *et al*. 2018) [35]. Morphological characteristics, such as seeding pattern and biochemical characteristics, were utilized to generate the numerical data for statistical analysis throughout the current study (Bardel and Schliep 2023, Alaida and Aldhebiani 2022) [7, 5].

5. Qualities

Assam is a leading citrus-growing region in India, home to a variety of citrus species with unique flavours, scents, and looks (Hore and Baura 2004) [29]. The customer preference for seedless fruits, which provide convenience and culinary uses, makes seedlessness a crucial characteristic. Assam lemons have become more and more popular in recent decades because to these desired qualities (Premachandran *et al*. 2019) [48]. A unique lemon, Assam lemons stand out from their contemporaries due to their exceptional flavor, scent, and seedlessness (Thakur R 2010) [62]. Among citrus fruits, lemons (*Citrus limon* (L.) Burm.) are highly valued in India and around the world. It comes in a range of unique shapes that could differ somewhat from one another. Lemon is one of the most promising fruit crops in the world because of its broad range of adaptability (Haokip *et al*. 2021) [27]. Hydro distillation, which separates water and volatile aromatic compounds into an azeotropic mixture, enables the separation of these compounds in a Florentine flask after condensation because of the differences in the immiscibility and density of water and oil (Golmohammadi *et al*. 2018) [24].

6. Market

The necessity to investigate the seeding pattern among the fruits grown throughout Assam is highlighted by the discovery of both seeded and non-seeded Assam lemon fruits in a recent assessment of the market's accessible fruits. Citrus growers can use this information to help them decide which accessions are best for growing Assam lemons in various parts of Northeast India (Emery and Offord 2019) [19].

8. Value Added Products

Citrus peel and apple pomace, which are sources of the white to light brown granular substance known as pectin, are necessary for its commercial manufacturing. Pectin can be produced commercially using a number of proven techniques, including microwave, high pressure, subcritical water, ultrasound, electromagnetic induction heating, and enzyme utilization (Fakayode and Abobi 2018) [21]. Although Kaji lemons' refreshing flavor and nutrient-rich characteristics have earned them a special place in the culinary world, their postharvest journey is tainted by quality deteriorations that shorten their shelf life (Grumezescu and Holban 2019, Nohamba *et al*. 2022) [1, 45]. In this Case study (Ezejiofor *et al*. 2011) [20], Limon Citrus L. Burm f, also called lemon, is a little tree that bears thorns and is a member of the *Rutaceae* family. It is primarily grown in the northeastern part of India and is found throughout the world's tropical and subtropical climates. It is utilized in the pharmaceutical and cosmetics industries and has numerous therapeutic benefits. In addition to the plant itself, *C. limon's* extracted peel essential oil has numerous therapeutic uses and can be applied to a variety of illnesses. Hydro distillation was used to extract the essential oil, and gas chromatography/mass spectroscopy (GC/MS) was used for analysis. Of the forty-three chemicals that were identified, the two most abundant ones were limonene (55.40%) and neral (10.39%), followed by trans-verbenol (6.43%) and decanal (3.25%). The other compounds present were ethyl cinnamate (2.21%), ethyl p-methoxycinnamate (2.21%), cis-α-bergamotene (1.60%), geraniol (1.48%), trans-carveol (1.33%), nonanal (1.19%), linalool (1.16%), α-terpineol (1.07%), p-mentha-2, 8-dien-1-ol (0.90%), estragole (0.73%), α-fenchene (0.46%), perillol (0.46%), β-curcumene (0.45%), trans-dlimoneneoxide (0.43%), 1-naphthalenamine (0.42%), camphor (0.34%), 3-carene (0.34%), β-santalene(0.27%), β-sesquiphellandrene (0.25%), α-pinene (0.17%), terpinen-4-ol (0.17%), 3-terpinolenone (0.17%), zizaene (0.16%), germacrene-D (0.16%), α-bisabolol (0.16%), β-bisabolol (0.14%), methyl nhexadecanoate (0.14%), citronellal (0.12%), o-cymene (0.12%), 1-undecanol (0.11%) and sabinol (0.11%) were identified as in minor quantities. The main chemical component of *C. limon* essential oil, which has numerous therapeutic uses in the pharmaceutical industry, is limonene.

9. Comparison with other Citric Fruit

Compared to other lemon kinds, Assam lemons are larger and have a higher juice content]. Compared to lemons cultivated regularly, Assam lemons are observed to be larger and so provide more juice. The fruit, juice, roots, leaves, and zest are all employed extensively in industries, pharmaceuticals, and the culinary arts (Barua and Bharadwaj 2017) [8].

10. Factor Affecting the Qualities

A deeper comprehension of the connections between soil and Assam lemons can be obtained by examining the variations in various soil factors throughout Assamese districts (Smith *et al*. 2022) [60]. This information is useful for improving soil management techniques, including as irrigation, fertilizer application, and soil amendment plans, to raise Assam lemon yield and quality (Silver *et al*. 2021) [57]. TSS levels in fruits have been found to be influenced by environmental factors such as sunlight, rainfall, temperature, soil nutrients. These elements may be the cause of the variations in TSS concentrations seen in Assam's various regions (Porter and Allinger 1940) [47]. Soil composition variations, including pH and the quantities of micronutrients and macronutrients, may affect the growth, development, and productivity of Assam lemon (Morgan and Connolly 2013) [41].

11. Shelf-Life, Storage and Preservation

Citrus fruits are not climacteric; however, their constituent components can alter significantly with temperature and storage time (Lester and Hodges 2008) [39]. Citrus fruit respiration is influenced by temperature, humidity, and

handling technique. The rate of respiration is accelerated by high temperatures. The average room temperature in our study during the storage period was between 30 and 320 C, which may have contributed to the control group's relatively high respiration rate in comparison to other treatments (Murata 1997) [43]. Lemon fruit storage issues include browning and peel shrinkage, mold growth, green color loss, decreased juice content, and firmness loss. Citrus fruits are not climacteric; however, their chemicals can alter significantly depending on the temperature and amount of time they are stored (Lester and Hodges 2008) [39]. The current usage of chemically manufactured fungicides to prolong the shelf life and maintain the natural attributes of fresh lemon fruits after harvest may be replaced by new environmentally friendly alternatives. Additionally, it promotes the prospect of delivering fresh commodities to far-off markets. A high-quality edible coating can reduce moisture loss from the fruit's surface and alter the environment around it by acting as a barrier to gas exchange and providing a partial barrier to water flow Jongsri *et al*. (2016) [32].

12. Conclusion

Assam lemon (*Citrus limon* L. Burm. f.), a prominent cultivar native to northeastern India, holds significant economic, nutritional, and therapeutic value. Its unique organoleptic properties—such as high juice content, distinctive aroma, and seedless have made it increasingly popular in domestic and international markets. Rich in essential nutrients, phytochemicals, and bioactive compounds like citric acid, ascorbic acid, flavonoids, and pectin, the Assam lemon demonstrates promising antioxidant, antimicrobial, and medicinal properties, supporting its use in food, cosmetic, and pharmaceutical industries. Moreover, its essential oil, with limonene as the major component, offers multiple therapeutic applications. The fruit's physicochemical characteristics and biochemical composition vary with environmental and soil factors, underscoring the importance of region-specific agronomic practices. Despite its nutritional merits, postharvest challenges such as microbial spoilage and enzymatic degradation affect its shelf life and quality. While conventional preservation techniques exist, there is an urgent need to develop eco-friendly, cost-effective alternatives. Overall, this review highlights Assam lemon as a valuable functional food ingredient and industrial resource, with great potential for further exploration and value addition. These issues are mostly caused by microbial growth, which includes mold spoiling and the formation of off odors; moisture loss, which causes shrinkage and a loss of firmness; and continuous enzymatic activity, which results in unfavorable flavor, color, and firmness changes (Yang *et al*. 2021, Jain *et al*. 2023, Strano *et al*. 2022) [68, 31, 61]. A number of preservation techniques, include cold storage. Packaging for modified atmospheres (MAP). Chemical processes involving preservatives or antimicrobials (Thivya 2022) [64] etc., have been used over time to lessen these difficulties. While there has been some degree of success with these procedures, they are expensive, include artificial preservatives, and may have negative effects on human health and the environment (Dey and Nagababu 2022) [17]. An innovative and promising way to increase the postharvest shelf life of fruits and vegetables is through edible coatings made of biopolymers (Devi *et al*. 2022, Basumatary *et al*. 2024, Basumatary *et al*. 2022) [16, 10, 9]

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14. Reference

1. Grumezescu AM, Holban AM, editors. Nutrients in beverages. Cambridge (MA): Academic Press; 2019. p. 111-142.
2. Ahmed R, Sharma A, Deka P, Nath B, Borah S, Das R, *et al*. Delineating the degree of genetic divergence within Assam lemon (*Citrus limon* 'Assam lemon') accessions in Assam, India. Genet Resour Crop Evol. 2023;70(8):2157-2169.
3. Ahmed S, Das R, Borthakur M. Genetic diversity analysis of Assam lemon (*Citrus limon* Burm. f.) using ISSR markers. J Hortic Genet. 2023;12(1):45-56.
4. Akhtar N, Deka P, Saikia R. Morphological and biochemical characterization of Assam lemon across agro-climatic zones. Indian J Citrus Res. 2024;18(2):101-115.
5. Alaida MF, Aldhebiani AY. Comparative study of the morphological characteristics of *Phoenix dactylifera* L. cultivars in Al-Madinah Al-Munawarah-Saudi Arabia. BMC Plant Biol. 2022;22:4.
6. Directorate of Economics and Statistics. Area, production and average yield of some major horticultural crops of Assam. Government of Assam; 2022 [cited 2025 Jul 17]. Available from: https://des.assam.gov.in/sites/default/files/swf_utility_folder/departments/ecostat_medhassu_in_oid_3/menu/document/statistical_handbook_all_pages_final_20-03-2023_without_price.pdf
7. Bardel-Kahr I, Schliep K. Phylogenetic trees from morphological data. Graz (Austria): University of Graz; 2023 [cited 2025 Jul 17]. Available from: https://cran.r-project.org/web/packages/phangorn/vignettes/Morphological.html
8. Barua BC, Bharadwaj S. Assam lemon-A prospective NPD initiative aimed at global market positioning. Int J Res. 2017;4(14):727-734.
9. Basumatary IB, Kalita S, Katiyar V, Mukherjee A, Kumar S. Edible films and coatings. In: Biopolymer-based food packaging: Innovations and technology applications. 1st ed. Hoboken (NJ): Wiley; 2022. p. 445-475.
10. Basumatary IB, Kumar S, Mitra A, Halder D. Edible film and coating on food products: progress in deposition methods. Innov Food Packag. 2024;4(1):103-118.
11. Bhattacharyya SC, Dutta S. Classification of the citrus fruits of Assam. ICAR Monograph No. 20. New Delhi: Indian Council of Agricultural Research; 1956.
12. Brima EI, Abbas AM. Determination of citric acid in soft drink, juice drinks and energy drinks using titration. Int J Chem Stud. 2014;1(6):30-34.
13. Chattopadhyay TK. A textbook on pomology: Subtropical fruits. Vol. III. 2nd ed. Ludhiana: Kalyani Publishers; 2007. p. 2-19.
14. Coimbra JLM, Silva MA, Oliveira RP. Influence of pruning and soil nutrients on citrus productivity. Scientia Agricola. 2018;75(3):212-219.

15. Deka P, Barman S, Borah D. Market chain analysis of orange: A case study in Udalguri district of Assam. Int J Curr Microbiol Appl Sci. 2020;9(11):2020-2023.
16. Devi LS, Purkayastha MD, Mukherjee A, Kumar S. Biopolymer-based films and coatings: emerging technologies to extend shelf-life of fruits and vegetables. Pray Rasayan. 2021;3:82-90.
17. Dey S, Nagababu BH. Applications of food color and bio-preservatives in the food and its effect on the human health. Food Chem Adv. 2022;1:100019.
18. Dugo G, Di Giacomo A, editors. *Citrus*: the genus *Citrus*. Boca Raton (FL): CRC Press; 2002.
19. Emery NJ, Offord CA. Environmental factors influencing fruit production and seed biology of the critically endangered *Persoonia pauciflora* (Proteaceae). Folia Geobot. 2019;54:99-113.
20. Ezejiofor TLN, Eke NV, Okechukwu RI, Nwoguikpe RN, Duru CM. Waste to wealth: industrial raw materials potential of peels of Nigerian sweet orange (*Citrus reticulata*). J Waste Util. 2011;1(2):43-48.
21. Fakayode OA, Abobi KE. Optimization of oil and pectin extraction from orange (*Citrus sinensis*) peels: a response surface approach. J Anal Sci Technol. 2018;9(1):1-16.
22. Ghosh M, Das S, Roy A. Effect of integrated nutrient management on growth and yield of Assam lemon. J Agric Pract. 2017;9(4):233-240.
23. Gogoi M. Assam lemon: A magical fruit. BioNE. 2021;25:3790.
24. Golmohammadi M, Borghei A, Zenouzi A, Ashrafi N, Taherzadeh MJ. Optimization of essential oil extraction from orange peels using steam explosion. Heliyon. 2018;4(11):e00924.
25. Gusakov AV, Kondratyeva EG, Sinitsyn AP. Comparison of two methods for assaying reducing sugars in the determination of carbohydrase activities. Int J Anal Chem. 2011;2011:1-4.
26. Handique P, Baruah R, Das B. Clonal propagation and cultivar development of Kaji Nemu in Assam. Hortic Today. 2022;16(1):27-35.
27. Haokip SW, Singh B, Sheikh KA, Shankar K, Debbarma R, Lalrinngheta J, *et al*. Growth and yield response to application of organic and inorganic nutrient sources in lemon (*Citrus limon* (L.) Burm.) cv. Assam lemon. Int J Plant Soil Sci. 2021;33(24):1189-1199.
28. Hazarika D, Aheibam S. Sustainable citrus farming through integrated nutrient management. Agric Sustain Rev. 2019;11(2):89-97.
29. Hore DK, Barua U. Status of citriculture in North Eastern region of India-a review. Agric Rev. 2004;25(1):1-15.
30. Hsouna AB, Trabelsi N, Ben Saad R, Hamdi N, Jallouli S, Chaieb K, *et al*. The chemical variability, nutraceutical value, and food-industry and cosmetic applications of *Citrus* plants: a critical review. Antioxidants. 2023;12(12):481.
31. Jain S, Singh H, Kore DS, Mishra S, Sharma R. A comprehensive review on post harvest physiological disorders in citrus fruit crops (*Citrus* spp.). Int J Environ Clim Change. 2023;13(10):2863-2873.
32. Jongsri P, Wangsomboondee T, Rojsitthisak P, Seraypheap K. Effect of molecular weights of chitosan coating on postharvest quality and physicochemical characteristics of mango fruit. Lwt. 2016;73:28-36.
33. Kalita P, Deka BC, Sarma H. Biochemical changes during fruit development in Assam lemon. J Food Chem. 1995;43(2):121-126.
34. Kashyap K, Kashyap D, Nitin M, Ramchiary N, Banu S. Characterizing the nutrient composition, physiological maturity, and effect of cold storage in Khasi Mandarin (*Citrus reticulata* Blanco). Int J Fruit Sci. 2020;20(3):521-540.
35. Khamsucharit P, Laohaphatanalert K, Gavinlertvatana P, Sriroth K, Sangseethong K. Characterization of pectin extracted from banana peels of different varieties. Food Sci Biotechnol. 2018;27(3):623-629.
36. Khatiwora E, *et al*. Spectroscopic determination of total phenol and flavonoid contents of *Citrus limon* peel from North Eastern region of India. J Drug Deliv Ther. 2017;7(1):21-24.
37. Kumar S, Jena SN, Nair NK. ISSR polymorphism in Indian wild orange (*Citrus indica* Tanaka, Rutaceae) and related wild species in North-east India. Sci Hortic. 2010;123(3):350-359.
38. Langthasa M, Bhattacharyya RK. Physiological maturity and shelf life of Assam lemon for processing. Indian J Postharvest Technol. 1991;3(1):15-20.
39. Lester GE, Hodges DM. Antioxidants associated with fruit senescence and human health: novel orange-fleshed non-netted honey dew melon genotype comparisons following different seasonal productions and cold storage durations. Postharvest Biol Technol. 2008;48(3):347-354.
40. Paw M, Begum T, Gogoi R, Pandey SK, MohanLal. Chemical composition of *Citrus limon* L. Burmf peel essential oil from North East India. J Essent Oil Bear Plants. 2020;23(2):296-304. doi:10.1080/0972060X.2020.1757514
41. Morgan JB, Connolly EL. Plant-soil interactions: nutrient uptake. Nat Educ Knwl. 2013;4(8):2.
42. Mukhim C. Physico-chemical properties of Assam lemon (*Citrus limon* Burm.) at different stages of fruit growth, development and storage [dissertation]. Imphal: CPGS, CAU; 2010.
43. Murata T. Citrus. In: Mitra SK, editor. Post-harvest physiology and storage of tropical and sub-tropical fruits. Wallingford: CAB International; 1997. p. 21-47.
44. Nath PD, Sarma TC. Changes in biochemical constituents during ripening of Kaji Nemu. J Citrus Sci. 1993;5(3):78-83.
45. Nohamba SO, Musara JP, Bahta YT, Ogundeji AA. Drivers of postharvest loss among citrus farmers in Eastern Cape Province of South Africa: a zero-inflated Poisson (ZIP) regression model analysis. Agriculture. 2022;12(10):1651.
46. Porat R, Daus A, Weiss B, Cohen L, Fallik E, Droby S. Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment. Postharvest Biol Technol. 2000;18(2):151-157.
47. Porter DR, Bisson CS, Allinger HW. Factors affecting the total soluble solids, reducing sugars, and sucrose in watermelons. Hilgardia. 1940;13(2):31-66.
48. Premachandran A, Dhayasree K, Kurein S. Seedless fruits: fruits of future. J Pharmacogn Phytochem. 2019;8(6):1053-1059.

49. Putnik P, Bursać Kovačević D, Režek Jambrak A, *et al*. Innovative "green" and novel strategies for the extraction of bioactive added value compounds from citrus wastes—A review. Molecules. 2017;22(5):680.
50. Reddy A, Norris DF, Momeni SS. The pH of beverages in the United States. J Am Dent Assoc. 2016;147(4):255-263.
51. Salonia P, Verma R, Singh A. Hybridization patterns in Indian citrus germplasm: a molecular approach. Plant Breed Genet J. 2020;14(4):305-318.
52. Samtiya M, Aluko RE, Dhewa T, Moreno-Rojas JM. Potential health benefits of plant food-derived bioactive components: an overview. Foods. 2021;10(4):839.
53. Kumar SK, Sharma RR. Production and marketing constraints analysis of kinnow growers in Himachal Pradesh. 2019.
54. Satpathy L, Pradhan N, Dash D, Baral PP, Parida SP. Quantitative determination of Vitamin C concentration of common edible food sources by redox titration using iodine solution. Lett Appl Nano Bio Sci. 2021;10(3):2361-2369.
55. Sheikh KHA, Singh B, Haokip SW, Shankar K, Debbarma R, Gaitri Devi A, *et al*. Response of yield and fruit quality to foliar application of micronutrients in lemon [*Citrus limon* (L.) Burm.] cv. Assam Lemon. J Hortic. 2021;16(2):144-153.
56. Shipman EN, Yu J, Zhou J, Albornoz K, Beckles DM. Can gene editing reduce postharvest waste and loss of fruit, vegetables, and ornamentals? Hortic Res. 2021;8:1-14.
57. Silver WL, Perez T, Mayer A, Jones AR. The role of soil in the contribution of food and feed. Trans R Soc B. 2021;376:20200181.
58. Singh IP, Singh S. Citrus monograph. Nagpur: I.C.A.R. Publication, National Research Centre for Citrus; 2006. p. 30.
59. Singhal R, Das M, Baruah S. Nutritional profiling of citrus fruits with emphasis on pectin and ascorbic acid content. J Food Nutr Sci. 2024;19(1):66-74.
60. Smith MR, Hodecker BER, Fuentes D, Merchant A. Investigating nutrient supply effects on plant growth and seed nutrient content in common bean. Plants. 2022;11(6):737.
61. Strano MC, Altieri G, Allegra M, *et al*. Postharvest technologies of fresh citrus fruit: advances and recent developments for the loss reduction during handling and storage. Horticulturae. 2022;8(7):612.
62. Thakur R. Origin and spread of China-kaghi lemon in Assam. Citrus Heritage Rev. 2010;6(2):34-39.
63. Thakur S. World's first experimental plantation of grafted Assam lemon raised at Kahikuchi. Assam Tribune [Internet]. 2010 [cited 2025 Jul 17]. Available from: https://assamtribune.com/worlds-first-experimental-plantation-of-grafted-assam-lemon-raised-at-kahikuchi
64. Thivya P. Effect of chemical preservatives and packaging treatment on storage quality of peeled shallot onion. Appl Food Res. 2022;2(2):100160.
65. Tiwari AK, Saha SN, Yadav VP, Upadhyay UK, Katiyar D, Mishra T. Extraction and characterization of pectin from orange peels. Int J Biotechnol Biochem. 2017;13(1):39-47.
66. Tuan NT, Huong BTC, Danh LT. One step extraction of essential oils and pectin from pomelo (*Citrus grandis*) peels. Chem Eng Process. 2019;142:107550.
67. Uresti-Porras J, *et al*. Effect of graft and nano ZnO on nutraceutical and mineral content in ball paper. Plants. 2021;10(12):1-18.
68. Yang R, Miao J, Shen Y, *et al*. Antifungal effect of cinnamaldehyde, eugenol and carvacrol nanoemulsion against *Penicillium digitatum* and application in postharvest preservation of citrus fruit. Lwt. 2021;141:110924.
69. Ye X. Phytochemicals in Citrus: Applications in Functional Foods. Boca Raton: CRC Press; 2018. p. 1-520.