



RESEARCH ARTICLE

# Physico-chemical and nutritional properties of wild jujube (*Ziziphus oenopolia* (L.) Mill.) fruits under different locations and storage conditions

Nikitasha Dash<sup>1\*</sup>, Gopa Mishra<sup>1\*</sup>, Sipra Mohapatra<sup>2\*</sup>, Nandita Jena<sup>3</sup>, Subrat Kumar Senapati<sup>4</sup>, Debi Archana Nayak<sup>5</sup> & Swastika Pal<sup>1</sup>

<sup>1</sup>Department of Fruit Science, Institute of Agricultural Sciences (IAS), Siksha 'O' Anusandhan Deemed To be University, Bhubaneswar 751 003, Odisha, India

<sup>2</sup>Department of Fruit Science and Horticulture Technology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar 751 003, Odisha, India

<sup>3</sup>Department of Plant Physiology, Institute of Agricultural Sciences (IAS), Siksha 'O' Anusandhan Deemed To be University, Bhubaneswar 751 003, Odisha, India

<sup>4</sup>Department of Floriculture and Landscaping, Institute of Agricultural Sciences (IAS), Siksha 'O' Anusandhan Deemed To be University, Bhubaneswar 751 003, Odisha, India

<sup>5</sup>Department of Vegetable Science, Institute of Agricultural Sciences (IAS), Siksha 'O' Anusandhan Deemed To be University, Bhubaneswar 751 003, Odisha, India

\*Correspondence email - [nikitashadash.rs22@ouat.ac.in](mailto:nikitashadash.rs22@ouat.ac.in); [gopamishra@soa.ac.in](mailto:gopamishra@soa.ac.in); [sipramohapatra.sm44@gmail.com](mailto:sipramohapatra.sm44@gmail.com)

Received: 05 February 2026; Accepted: 19 June 2026; Available online: Version 1.0: 24 August 2026

**Cite this article:** Nikitasha D, Gopa M, Sipra M, Nandita J, Subrat KS, Debi AN, Swastika P. Physico-chemical and nutritional properties of wild jujube (*Ziziphus oenopolia* (L.) Mill.) fruits under different locations and storage conditions. Plant Science Today. 2026; 13(sp5): 1-8. <https://doi.org/10.14719/pst.14007>

## Abstract

*Ziziphus oenopolia* (L.) Mill. is a wild nutraceutical plant, belonging to Rhamnaceae family. It is an important shrub which is mostly found in warm tropical Asia and northern Australia. Since time immemorial this plant is best known for its ayurvedic properties. Furthermore, it is recognised for its therapeutic efficiency in curing different diseases all over the globe. *Ziziphus oenopolia* produces cyclopeptide alkaloids called ziziphines and has major role in biomedical applications. It has antioxidant, antibacterial, antimicrobial, antihepatotoxicity, antiulcer, wound healing, anti-plasmodial and anticancer activity. The objective of this study was to characterise the physico-chemical and nutritional properties of wild jujube (*Z. oenopolia*) fruits grown in different locations and in various storage conditions. Fruits were collected from multiple locations and analysed for physico-chemical parameters (fruit weight, total soluble solids (TSS), sugar content, ascorbic acid, phenolic compounds) and nutritional composition at full-ripe stage under different storage treatments. Soil nutrient levels and leaf chlorophyll content were also measured to assess their influence on fruit composition. The results showed that TSS and sugar content increased with storage, while ascorbic acid decreased. Fruit weight and quality varied with location and storage conditions and soil nutrients and leaf chlorophyll affected fruit composition. In conclusion, these fruits are a rich source of minerals and antioxidants with good shelf life, making them a promising candidate for food and medicinal use also their physico-chemical properties are influenced by location and storage conditions. Further research on domestication and optimal storage is recommended for improving fruit quality and utilisation.

**Keywords:** antioxidant; nutritional; phenolic; storage duration; therapeutic; wild ber

## Introduction

Ber or Indian jujube (*Ziziphus oenopolia* (L.) Mill.) has been recognised as the under-utilised fruit since ancient times in India. It belongs to family Rhamnaceae. Origin of ber fruit is Central Asia. It can tolerate temperatures ranges from 39–42 °C and it can also tolerate temperature up to 50 °C but above this the tree cannot withstand much temperature because fruit set is hampered if the temperature goes above 35 °C (1). The morphology of the ber fruit is glabrous, globose, or oval. Drupe size varies from 1–2 cm in diameter but in oval cultivars diameter varies from 4–6 cm. As it is an arid fruit crop it can withstand drought. It is considered the 'king of Fruits' in

arid regions. It is also called as Poor man's fruit. It's fruit is an important source of energy which is used by many tribal people. Many poor people or tribals cannot afford fruits from market as the cost of the fruits are even higher and they are richest source of vitamin C, so they mainly depend on the forest trees like ber, amla, etc. which is exceptionally rich in vitamin C. All species of ber tree has a spreading and branching habit. Shape of the fruit varies from oblong, ovoid, globose and glabrous. Fruits when it is small, it is green in colour and when it matures colour changes from green to blackish having white flesh and juicy. It is sour when it is ripe and sweet when it is in fully ripe condition. This species is distributed throughout all parts and it always adapt to the warm to hot tropical

climates with low or relatively heavy rainfall. As it is an arid fruit crop, it can be best grown in wastelands and marginal areas and it needs no care for its survival. Minimal inputs and maintenance are required, yet the plant remains important source for many poor people in the rural areas. Ber fruits are eaten raw (fresh) and used as processed products like jelly, jam, murabba, squash, candies, wine, slices and powders. Acid type of ber is used for making chutneys and pickles (2–6). Ber fruit is rich in its nutritive value, very popular and cheap for which it is called as Poor man's fruit. It is also a rich source of Vitamin C, B, A and calcium (Ca), potassium (K), rubidium (Rb) and bromine (Br) (7). Ber fruits contained carbohydrates, proteins, vitamins, moisture, fat, iron, Ca, phosphorus, carotene, thiamine, riboflavin, sugars, ascorbic acid, fibres and calorific value (8–10). Amino acids such as aspartic acid, glutamic acid, threonine, asparagine and glycine were found in the pulp of ber cultivars (11). Ber trees even have very good values along with the fruits and leaves are applied as poultices to treat liver ailments like asthma and fever and used as a folk herbal medicine used as an abdominal pain killer and anti-diarrheal agent. It has many pharmacological activities like it helps in purifying blood, febrifuge, etc. Plants produced cyclopeptide alkaloids called as Ziziphines which is used as herbal medicine in ancient times. In India people use its roots as an ayurvedic medicine. In Burma, people used its stem as a mouth wash for sore throat, inflammation of uterus and for dysentery. Konkani people of Maharashtra used its chewed leaves for dressing of the wounds. Extracts of ziziphine from *Z. oenopolia* show antiplasmodial *in vitro* activity against the malarial parasite *Plasmodium falciparum*. There is lack of data on post-harvest handling and storage has hindered its widespread adoption. Given the fruit's nutritional importance and potential for value addition, it is essential to characterise its physico-chemical and nutritional properties under different storage conditions. Objective is to characterise the physico-chemical and nutritional properties of wild jujube (*Z. oenopolia*) fruits grown in different locations and subjected to various storage conditions. Therefore, new and innovative research are being done to bring this under-utilised fruit into the market for which rural as well as urban people should know its multiple use and consume for their betterment as this ignored or under-utilised fruit is rich in more of Vitamin C after Barbados cherry. Furthermore, additional studies were needed to develop the processing of ber cultivars.

## Materials and Methods

The experiment was carried out in the Post Graduate Horticulture laboratory of Siksha 'O' Anusandhan (Deemed to be university), during the year 2021–22. The fruits of wild jujube (*Z. oenopolia*) were collected from 3 different locations of Odisha like Bhawanipatna, Kamthana and Bharatpur areas. The latitude and longitude of Bhawanipatna is 19.90°N and 83.16°E. Kamthana is situated at 19.96°N and 83.13°E, Bharatpur is located at 20.27°N and 85.79°E. Bhawanipatna and Kamthana recorded maximum and minimum temperatures of 29 °C and 23 °C with humidity at 81 % and 84 % respectively, while Bharatpur registered 25 °C and 31 °C with 81 % humidity. The fresh fruits and leaves were collected from each location. The observations like leaf area and fruit physical and fruit chemical parameters of wild jujube (Kanteikoli) were recorded.

## Treatment details

The experiment was laid out in completely randomised design (CRD) with nine treatments and six replications. The treatment allotments

are as follows: fruits were collected from Bhawanipatna, i.e., T<sub>1</sub>: Bhawanipatna sample (fresh); T<sub>2</sub>: Bhawanipatna sample + 1 week storage; T<sub>3</sub>: Bhawanipatna sample + 2 weeks storage; fruits were collected from Kamthana, i.e., T<sub>4</sub>: Kamthana (fresh); T<sub>5</sub>: Kamthana sample + 1 week storage; T<sub>6</sub>: Kamthana + 2 weeks storage; T<sub>7</sub>: Bharatpur sample (fresh); T<sub>8</sub>: Bharatpur sample + 1 week storage; T<sub>9</sub>: Bharatpur + 2 weeks storage. 300 fruits were collected for 6 replications. Fruits were collected when they were unripe or green immature stage characterised by a colour change from green to red and then blackish. Fruits were harvested based on uniform size, green colour and absence of damage.

## Storage condition

The fruits were stored under two different conditions: controlled ambient storage and cold storage. In controlled ambient storage, the temperature was maintained at 27 °C with a relative humidity ranging between 85–90 %. In cold storage, the temperature ranged from 0–5 °C with a relative humidity between 85–95 %. Observations were recorded at intervals of 7 days to monitor changes under these storage conditions.

## Leaf area and chlorophyll content

Five leaves were collected from sample plants from each replication; leaf area was measured using a leaf area meter.

Leaf chlorophyll was calculated by using acetone method (12). Chlorophyll a, b and total chlorophyll contents were calculated in mg/g fresh weight, mg/g dry weight and mg/cm<sup>2</sup> or dm<sup>2</sup> of the leaf by using following formulas:

Chlorophyll-a (mg/g fw or mg/g dw or mg/dm<sup>2</sup>) =

$$[12.7 \times D_{663} - 2.69 \times D_{645}] \times V / (1000 \times W_F \text{ or } W_D \text{ or dm}^2)$$

Chlorophyll-b (mg/g fw or mg/g dw or mg/dm<sup>2</sup>) =

$$[22.9 \times D_{645} - 4.68 \times D_{663}] \times V / (1000 \times W_F \text{ or } W_D \text{ or dm}^2)$$

Total chlorophyll (mg/g fw or mg/g dw or mg/dm<sup>2</sup>) =

$$[20.2 \times D_{645} - 8.02 \times D_{663}] \times V / (1000 \times W_F \text{ or } W_D \text{ or dm}^2)$$

Where, D<sub>645</sub> = optical density (O.D.) value of 645 nm, D<sub>663</sub> = O.D. value of 663 nm, V = volume of 80 % acetone chlorophyll extract in mL, W<sub>F</sub> = fresh weight of the leaf (g) used for chlorophyll extraction, W<sub>D</sub> = dry weight of leaf in gram used for chlorophyll extraction (i.e., dry weight of 100 mg fresh leaf kept in oven for drying), dm<sup>2</sup> = leaf area in square decimetre.

## Fruit physico-chemical characters

The observations of fruits were also recorded i.e., fruit physico-chemical characters like individual fruit weight were measured by placing fruits on the electrical weighing balance and recorded in grams (g).

Fruits total soluble solids (TSS) were determined by using Digital Refractometer according to standard procedure and expressed in (°Brix) (13).

The total sugar content of fruit was determined using the "Lane and Eynon" method, wherein 50 mL of filtered juice was diluted with 100 mL of distilled water and neutralised with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as indicator (14). The results were expressed in % (g sucrose/ 100 g fresh weight). The titratable acidity of wild jujube (*Z. oenopolia*) fruit was determined by titrating the sample against 0.1 N NaOH using phenolphthalein as an indicator (15). It was expressed as (%). The phenolic content was estimated following standard procedures (16, 17). The units were expressed in mg fresh

weight. The carbohydrate content was determined by the prescribed method (18). Units were expressed in mg/100 g fresh weight. The ascorbic acid content was determined by the standard method (19). Units were expressed in mg/100 g fresh weight.

### Nutritional content

The nutritional content of fruits was also recorded i.e., iron constituent was determined using Atomic Absorption Spectroscopy (AAS) (20). Fruit samples were digested (acid digestion) and analysed by AAS and expressed in (mg FE/100 g fresh weight).

The phosphorus content of collected fruits of wild ber were determined with the help of digestion with di-acid (nitric acid ( $\text{HNO}_3$ ) + (perchloric acid ( $\text{HClO}_4$ )) followed by spectrophotometric determination (21). Samples were digested with  $\text{HNO}_3$  +  $\text{HClO}_4$ , then phosphorus was quantified spectrophotometrically and units are expressed in mg P/100 g fresh weight.

The K content of collected fruits of *Z. oenopolia* was determined by using di-acid digestion followed by Flame photometric determination method (21). Samples were digested with di-acid then K was measured by flame photometry. Units are expressed in mg K/ 100 g fresh weight.

### Statistical analysis

The experimental data recorded for different physico-chemical parameters of fruits were subjected to statistical analysis to determine the degree of variation among the treatments. The data were analysed statistically using CRD (22). The analysis of variance (ANOVA) was carried out to test the significance of treatment effects (Table 1). The significance of differences among treatment means was tested by 'F' test at 5 % level of significance. Whenever the

**Table 1.** Analysis of variance

| Source    | Degree of freedom (d.f.) | Sum of square | Mean sum of square | F calculated value | Ft 5 % table value |
|-----------|--------------------------|---------------|--------------------|--------------------|--------------------|
| Treatment | t-1                      | TrSS          | TrMS               | TrMS/EMS           | -                  |
| Error     | t(r-1)                   | ESS           | EMS                | -                  | -                  |
| Total     | rt-1                     | TSS           | -                  | -                  | -                  |

Where, r: number of replications; t: number of treatments; TrSS: treatment sum of squares; ESS: error sum of squares; TSS: total sum of squares; TrMS: treatment mean sum of squares; EMS: error mean sum of squares; F: Fisher's variance ratio.

treatment effects were found significant, the standard error of mean [SE m ( $\pm$ )], critical difference (CD) at  $p = 0.05$  and coefficient of variation (CV %) were calculated for comparison of treatment means. The statistical analysis was carried out using MS-Excel and OPSTAT software.

The 'F' test was applied to judge overall significance of various treatments in general and comparison of individual treatment performed with the help of CD at 5 % level of significance, which was computed as given below:

$$\text{SE m } (\pm) = \sqrt{\text{EMS}/r}$$

$$\text{SE (d)} = \sqrt{2\text{EMS}/r}$$

$$\text{CD } (p=0.05) = \text{SE (d)} \times t_{(0.05, \text{error d.f})}$$

$$\text{CV } (\%) = \sqrt{\text{EMS}/X} \times 100$$

Where, SE m ( $\pm$ ): standard error of mean; SE (d): standard error of difference between two treatment means;

CD: critical difference; EMS: error mean sum of squares; r: number of replications; X: overall mean; t: tabulated 't' value at error degrees of freedom.

### Results

Fruits of *Z. oenopolia* (Kanteikoli) were stored at controlled ambient storage conditions (25–27 °C). The observations pertain exclusively to these conditions; no cold storage data were included. A broad variation in physico-chemical parameters was recorded and presented below:

In Table 2, the individual fruit weight was determined at the full-ripe stage in ambient storage. The maximum fruit weight (0.31g) was observed in fresh Bhawanipatna fresh sample of full ripe stage, while the minimum weight (0.173g) was recorded for Bharatpur samples stored for two weeks post-full-ripe stage. The slight variation observed in fruit weight during storage could be associated

**Table 2.** Individual fruit weight (g) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment         | Treatment details                   | Individual fruit weight (g) full ripe |
|-------------------|-------------------------------------|---------------------------------------|
| T <sub>1</sub>    | Bhawanipatna (fresh)                | 0.31                                  |
| T <sub>2</sub>    | Bhawanipatna + 1 week after storage | 0.28                                  |
| T <sub>3</sub>    | Bhawanipatna + 2 week after storage | 0.185                                 |
| T <sub>4</sub>    | Kamthana (fresh)                    | 0.30                                  |
| T <sub>5</sub>    | Kamthana + 1 week after storage     | 0.279                                 |
| T <sub>6</sub>    | Kamthana + 2 week after storage     | 0.22                                  |
| T <sub>7</sub>    | Bharatpur (fresh)                   | 0.235                                 |
| T <sub>8</sub>    | Bharatpur + 1 week after storage    | 0.232                                 |
| T <sub>9</sub>    | Bharatpur + 2 week after storage    | 0.173                                 |
| CD ( $p = 0.05$ ) |                                     | 0.05                                  |
| SE (m) $\pm$      |                                     | 0.02                                  |

with moisture loss through transpiration and respiratory metabolism, leading to gradual reduction in fresh weight with advancement of storage period. Fruits stored for two weeks exhibited comparatively lower weight, indicating higher physiological loss in weight under ambient conditions.

The TSS were measured at full ripe stage. Significant differences were found among treatments, with the highest TSS (25.17 °Brix) in Bharatpur fruits stored for two weeks. The TSS ranged from 7.04 °Brix to 25.17 °Brix at full ripeness and increased with storage duration, reaching maximum after two weeks (Table 3). The progressive increase in TSS during ambient storage may be attributed to hydrolysis of complex carbohydrates such as starch, pectin and polysaccharides into simpler soluble sugars during ripening. Enhanced metabolic activity and moisture loss during storage might have further concentrated soluble solids, resulting in higher TSS values in fruits stored for longer durations. Similar increases in TSS during storage have been reported in several climacteric and semi-climacteric fruits.

Titrateable acidity was measured in full ripe stage. Ber fruits were kept in controlled ambient storage ranged from 0.40–0.52 % (Table 4). Titrateable acidity showed comparatively narrow variation among treatments, which may be due to utilisation of organic acids

**Table 3.** Total soluble solids (°Brix) at different stages of maturity of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment                         | Treatment details                   | Total soluble solids (°Brix) full ripe |
|-----------------------------------|-------------------------------------|----------------------------------------|
| T <sub>1</sub>                    | Bhawanipatna (fresh)                | 7.12                                   |
| T <sub>2</sub>                    | Bhawanipatna + 1 week after storage | 7.13                                   |
| T <sub>3</sub>                    | Bhawanipatna + 2 week after storage | 7.04                                   |
| T <sub>4</sub>                    | Kamthana (fresh)                    | 9.75                                   |
| T <sub>5</sub>                    | Kamthana + 1 week after storage     | 9.74                                   |
| T <sub>6</sub>                    | Kamthana + 2 week after storage     | 9.75                                   |
| T <sub>7</sub>                    | Bharatpur (fresh)                   | 25.06                                  |
| T <sub>8</sub>                    | Bharatpur + 1 week after storage    | 25.14                                  |
| T <sub>9</sub>                    | Bharatpur + 2 week after storage    | 25.17                                  |
| <b>CD (<math>p = 0.05</math>)</b> |                                     | <b>2.68</b>                            |
| <b>SE (m)±</b>                    |                                     | <b>0.90</b>                            |

**Table 4.** Titratable acidity (%) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment                         | Treatment details                   | Titrateable acidity % full ripe |
|-----------------------------------|-------------------------------------|---------------------------------|
| T <sub>1</sub>                    | Bhawanipatna (fresh)                | 0.52                            |
| T <sub>2</sub>                    | Bhawanipatna + 1 week after storage | 0.42                            |
| T <sub>3</sub>                    | Bhawanipatna + 2 week after storage | 0.40                            |
| T <sub>4</sub>                    | Kamthana (fresh)                    | 0.47                            |
| T <sub>5</sub>                    | Kamthana + 1 week after storage     | 0.45                            |
| T <sub>6</sub>                    | Kamthana + 2 week after storage     | 0.42                            |
| T <sub>7</sub>                    | Bharatpur (fresh)                   | 0.46                            |
| T <sub>8</sub>                    | Bharatpur + 1 week after storage    | 0.45                            |
| T <sub>9</sub>                    | Bharatpur + 2 week after storage    | 0.41                            |
| <b>CD (<math>p = 0.05</math>)</b> |                                     | <b>0.06</b>                     |
| <b>SE (m)±</b>                    |                                     | <b>0.02</b>                     |

as respiratory substrates during storage. The decline in acidity with ripening is commonly associated with conversion of organic acids into sugars and other metabolites.

The highest total sugar was measured in full ripe stage and ber fruits in controlled ambient storage condition was (6.70 %) found in T<sub>9</sub>, whereas lowest total sugar (6.15 %) was recorded T<sub>1</sub> (Table 5). The increase in total sugars and total soluble carbohydrates (TSC) during storage may be attributed to enzymatic degradation of reserve polysaccharides into simple sugars such as glucose, fructose and sucrose. This biochemical transformation contributes to improvement in sweetness and palatability of the fruits at advanced ripening stages.

Total soluble carbohydrates were assessed in full- ripe fruit samples. The TSC in the fresh Bhawanipatna sample was

**Table 6.** Total soluble carbohydrates (mg/100 g fresh weight) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment                         | Treatment details                   | Total soluble carbohydrates (mg/100 g fresh weight) |
|-----------------------------------|-------------------------------------|-----------------------------------------------------|
| T <sub>1</sub>                    | Bhawanipatna (fresh)                | 15.23                                               |
| T <sub>2</sub>                    | Bhawanipatna + 1 week after storage | 17.29                                               |
| T <sub>3</sub>                    | Bhawanipatna + 2 week after storage | 23.56                                               |
| T <sub>4</sub>                    | Kamthana (fresh)                    | 16.21                                               |
| T <sub>5</sub>                    | Kamthana + 1 week after storage     | 19.56                                               |
| T <sub>6</sub>                    | Kamthana + 2 week after storage     | 25.21                                               |
| T <sub>7</sub>                    | Bharatpur (fresh)                   | 16.92                                               |
| T <sub>8</sub>                    | Bharatpur + 1 week after storage    | 19.76                                               |
| T <sub>9</sub>                    | Bharatpur + 2 week after storage    | 26.23                                               |
| <b>CD (<math>p = 0.05</math>)</b> |                                     | <b>3.38</b>                                         |
| <b>SE (m)±</b>                    |                                     | <b>1.14</b>                                         |

15.23 mg/100 g, increased to 17.29 mg/100 g after one week and 23.56 mg/100 g after two weeks. For Kamthana sample, TSC values were 16.21 mg/100 g (fresh), 19.56 mg/100 g (one week) and 25.21 mg/100 g (two weeks) (Table 6).

Ascorbic acid content, in controlled ambient storage was highest in fresh sample of full mature Kamthana sample (19.42 mg/100 g) and was statistically at par with treatments T<sub>1</sub> and T<sub>7</sub> (Table 7). Ascorbic acid content was higher in fresh fruits and

**Table 7.** Ascorbic acid at different stages of maturity (mg/100 g fresh weight) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment                         | Treatment details                   | Ascorbic acid (mg/100 g fresh weight) Full ripe |
|-----------------------------------|-------------------------------------|-------------------------------------------------|
| T <sub>1</sub>                    | Bhawanipatna (fresh)                | 19.14                                           |
| T <sub>2</sub>                    | Bhawanipatna + 1 week after storage | 15.56                                           |
| T <sub>3</sub>                    | Bhawanipatna + 2 week after storage | 12.22                                           |
| T <sub>4</sub>                    | Kamthana (fresh)                    | 19.42                                           |
| T <sub>5</sub>                    | Kamthana + 1 week after storage     | 15.71                                           |
| T <sub>6</sub>                    | Kamthana + 2 week after storage     | 13.01                                           |
| T <sub>7</sub>                    | Bharatpur (fresh)                   | 19.31                                           |
| T <sub>8</sub>                    | Bharatpur + 1 week after storage    | 16.03                                           |
| T <sub>9</sub>                    | Bharatpur + 2 week after storage    | 13.56                                           |
| <b>CD (<math>p = 0.05</math>)</b> |                                     | <b>2.10</b>                                     |
| <b>SE (m)±</b>                    |                                     | <b>0.71</b>                                     |

**Table 5.** Total sugar, non-reducing sugar and reducing sugar (mg/100 g fresh weight) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment                         | Treatment details                   | Reducing sugar (mg/100 g fresh weight) | Non reducing sugar (mg/100 g fresh weight) | Total sugar (mg/100 g fresh weight) |
|-----------------------------------|-------------------------------------|----------------------------------------|--------------------------------------------|-------------------------------------|
| T <sub>1</sub>                    | Bhawanipatna (fresh)                | 0.74                                   | 5.41                                       | 6.15                                |
| T <sub>2</sub>                    | Bhawanipatna + 1 week after storage | 0.76                                   | 5.45                                       | 6.21                                |
| T <sub>3</sub>                    | Bhawanipatna + 2 week after storage | 0.78                                   | 5.49                                       | 6.27                                |
| T <sub>4</sub>                    | Kamthana (fresh)                    | 0.73                                   | 5.49                                       | 6.29                                |
| T <sub>5</sub>                    | Kamthana + 1 week after storage     | 0.76                                   | 5.57                                       | 6.33                                |
| T <sub>6</sub>                    | Kamthana + 2 week after storage     | 0.79                                   | 5.59                                       | 6.38                                |
| T <sub>7</sub>                    | Bharatpur (fresh)                   | 0.91                                   | 5.61                                       | 6.52                                |
| T <sub>8</sub>                    | Bharatpur + 1 week after storage    | 1.03                                   | 5.65                                       | 6.68                                |
| T <sub>9</sub>                    | Bharatpur + 2 week after storage    | 1.07                                   | 5.69                                       | 6.70                                |
| <b>CD (<math>p = 0.05</math>)</b> |                                     | <b>0.13</b>                            | <b>0.92</b>                                | <b>0.82</b>                         |
| <b>SE (m)±</b>                    |                                     | <b>0.04</b>                            | <b>0.31</b>                                | <b>0.28</b>                         |

showed a decline in trend during storage, which could be due to oxidative degradation of ascorbic acid by enzymes such as ascorbate oxidase, coupled with increased respiration and exposure to ambient oxygen. Loss of vitamin C during postharvest storage is a common physiological phenomenon in fruit tissues.

In Fig. 1, the result of experimental studies showed that in ambient storage condition the total K concentration in the ripe fruit samples ranged from 0.217–0.231 mg/100 g. The minimum K level was observed in fresh sample of Bhawanipatna, whereas the maximum was detected in the Kamthana sample stored for two weeks.

The total phosphorus concentration in ambient-stored ripe fruits varied between 0.020–0.027 mg/100 g, indicating a narrow distribution of phosphorus across the studied varieties.

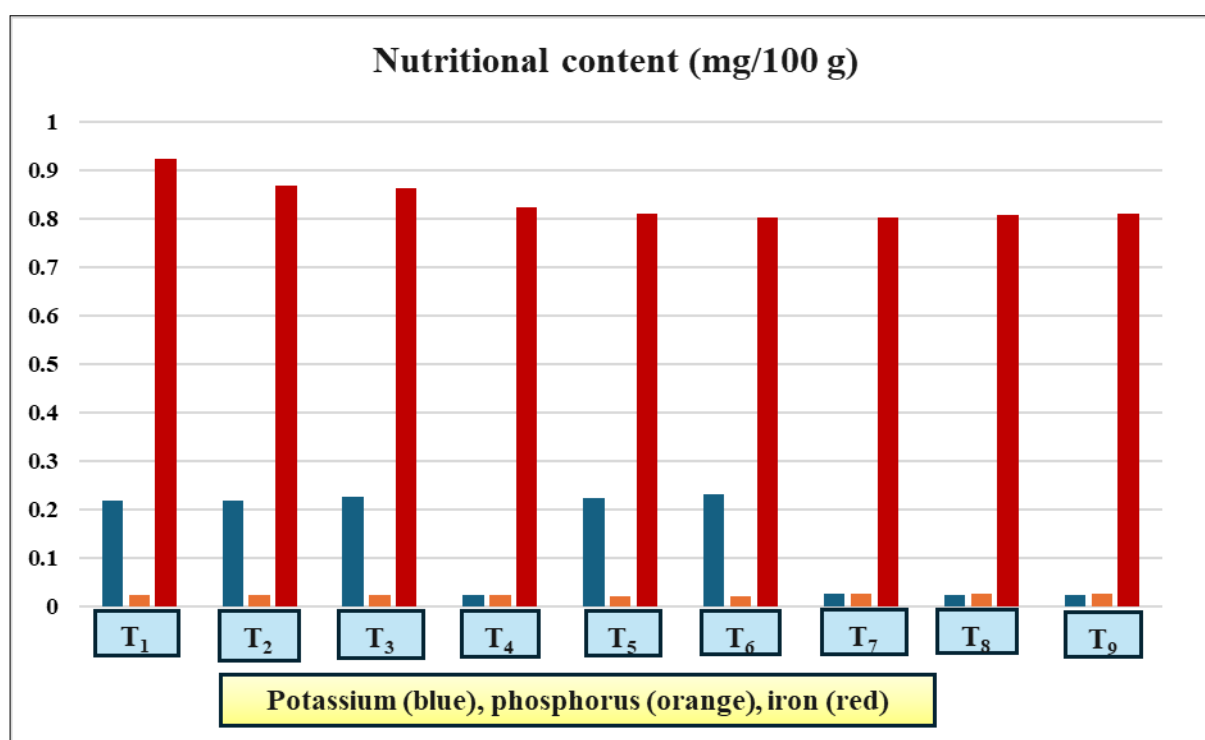
Ambient storage of ripe ber fruits resulted in total iron concentration spanning from 0.801–0.923 mg/100 g, indicating notable variation in iron accumulation in fruit tissues. The slight increase in K, phosphorus and iron concentrations during storage may be attributed to concentration effects caused by moisture loss and redistribution of mineral constituents within fruit tissues during ripening and senescence (Table 8).

It is seen that the total phenolic compounds were highest in fresh fruit samples and exhibited a temporal modulation, an initial decline was recorded at one week post storage, followed by a subsequent increase at two weeks, as illustrated in Fig. 2. Total phenolic compounds were highest in fresh fruits, decreased during initial storage and subsequently increased after prolonged storage. The initial reduction may be due to enzymatic oxidation of phenolics by polyphenol oxidase, whereas the later increase could be associated with stress-induced synthesis of secondary metabolites under prolonged storage conditions.

Overall, ambient storage significantly influenced the physico-chemical composition of *Z. oenopolia* fruits by promoting ripening-associated biochemical changes, including sugar accumulation, acid utilisation, vitamin degradation and modulation of antioxidant compounds, thereby affecting overall fruit quality.

## Discussion

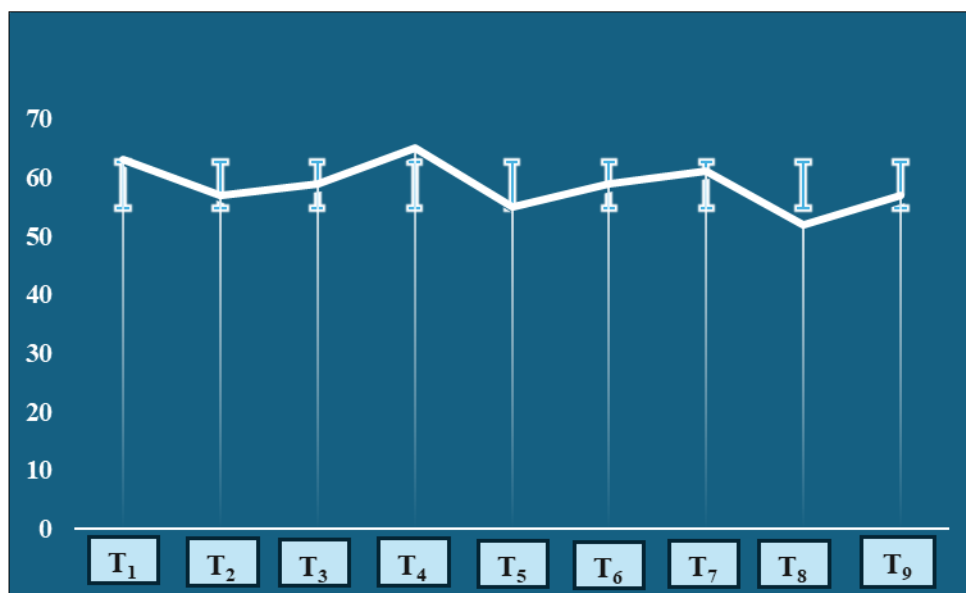
The carbohydrate content increases in the fruit to a certain extent before breaking down into sugars. Moisture content also decreases with increase period of storage (23, 24). Due to hydrolysis of polysaccharides and dehydration of fruits there was increase in TSS.



**Fig. 1.** Effect of different storage condition (mg/100 g fresh weight) on nutritional content of *Ziziphus oenopolia*.

**Table 8.** Nutritional content (mg/100 g) of *Ziziphus oenopolia* fruits in full ripe stage

| Treatment      | Treatment details                   | Potassium<br>(mg/100 g fresh<br>weight) | Phosphorus<br>(mg/100 g fresh<br>weight) | Iron<br>(mg/100 g fresh<br>weight) |
|----------------|-------------------------------------|-----------------------------------------|------------------------------------------|------------------------------------|
| T <sub>1</sub> | Bhawanipatna (fresh)                | 0.217                                   | 0.024                                    | 0.923                              |
| T <sub>2</sub> | Bhawanipatna + 1 week after storage | 0.218                                   | 0.023                                    | 0.867                              |
| T <sub>3</sub> | Bhawanipatna + 2 week after storage | 0.226                                   | 0.023                                    | 0.863                              |
| T <sub>4</sub> | Kamthana (fresh)                    | 0.024                                   | 0.023                                    | 0.823                              |
| T <sub>5</sub> | Kamthana + 1 week after storage     | 0.029                                   | 0.021                                    | 0.811                              |
| T <sub>6</sub> | Kamthana + 2 week after storage     | 0.231                                   | 0.020                                    | 0.801                              |
| T <sub>7</sub> | Bharatpur (fresh)                   | 0.025                                   | 0.027                                    | 0.802                              |
| T <sub>8</sub> | Bharatpur + 1 week after storage    | 0.023                                   | 0.026                                    | 0.807                              |
| T <sub>9</sub> | Bharatpur + 2 week after storage    | 0.024                                   | 0.025                                    | 0.811                              |
|                | <b>CD (<math>p = 0.05</math>)</b>   | <b>0.02</b>                             | <b>0.00</b>                              | <b>0.12</b>                        |
|                | <b>SE (m)±</b>                      | <b>0.01</b>                             | <b>0.00</b>                              | <b>0.04</b>                        |



**Fig. 2.** Effect of different storage condition on phenol content (mg fresh weight) of *Ziziphus oenopolia*.

The TSS was found to be increased from 12.25–15.96 °Brix and 25.17 °Brix and then got decreased to 12.26 °Brix in the over mature stage. The fruit TSS was measured least in over mature stage ranging from 6.37–12.26 °Brix in different treatments. It was observed that the TSS was increased with increased period of storage. The increase in TSS observed during ambient storage of *Z. oenopolia* fruits may be attributed to progressive hydrolysis of complex carbohydrates, including starch, pectin and other polysaccharides, into simpler soluble sugars during ripening. Simultaneously, reduction in fruit moisture content due to transpiration and respiration under ambient conditions might have resulted in concentration of soluble solids, thereby contributing to higher TSS values during storage. In the present investigation, TSS increased progressively from the fresh stage to two weeks of storage, indicating active ripening-associated biochemical changes. Similar observations have been reported in *Ziziphus mauritiana* Lam. and other minor fruits, where carbohydrate degradation and moisture loss were identified as major factors responsible for enhancement of soluble solids during storage.

A gradual decline in titratable acidity was observed with advancement of storage period, which may be attributed to utilisation of organic acids as respiratory substrates and their conversion into sugars and other metabolites during ripening. Such reduction in acidity, coupled with increase in TSS, improves the sugar-acid balance and enhances fruit palatability. Similar trends have been reported in ber and other tropical fruits during post-harvest storage. There was gradual decrease in acidity with the progression of storage.

Storage conditions significantly affect the total sugar content of *Z. oenopolia* fruits. It was found that the TSC is increased in fresh sample and after 1 week of storage and increased over storage. The increase in TSC recorded during storage may be due to enzymatic breakdown of reserve carbohydrates into simple sugars such as glucose, fructose and sucrose. Degradation of starch, which serves as an important storage polysaccharide in immature fruits, contributes significantly to sweetness development and improvement in eating quality during ripening. Comparable findings have also been reported in ber fruits, where storage-induced starch hydrolysis resulted in increased sugar accumulation.

Ascorbic acid content showed variation with maturity and storage period. Higher ascorbic acid content in fresh and fully mature fruits indicates active biosynthesis during fruit development, whereas subsequent decline during prolonged storage may be associated with oxidative degradation by enzymes such as ascorbate oxidase, increased respiratory activity and exposure to atmospheric oxygen. The ascorbic acid is an important antioxidant which strengthen the immune system of human body. The higher ascorbic acid content with higher TSS is regarded as good quality indicator for any wild fruit. With the maturity period the chemical characters also change like the fruit physical parameters. The ascorbic acid content was found to be increased over the maturity period of the fruit irrespective of places of collection. The carbohydrate content varied due to the decrease in moisture content, different break down process during the fruit maturity (25). Starch which is the main polysaccharides in many unripe fruits and found to be degraded with the advancement of ripening resulting in more sweetness and textural changes in ripe fruit than the unripe one (26). Similar observations were also found in ber (27). Since ascorbic acid is an important antioxidant and quality parameter, its retention in fresh fruits indicated superior nutritional quality.

Nutrient analysis is important for any fruit crop. Besides ascorbic acid and sugars, the nutrient content of the fruit indicates its nutritional value. The wild fruit (Kanteikoli) contained an appreciable amount of K, iron, phosphorus. The iron content of *Z. oenopolia* was ranging from 0.801 mg/100 g to 0.923 mg/100 g. The present findings are like earlier report (28). However, a study reported that the iron content of *Z. oenopolia* was 4.28 mg/100 g (29). Mineral analysis revealed appreciable concentrations of K, phosphorus and iron in the fruits, indicating the nutritional significance of Kanteikoli fruits. The slight increase in mineral concentration during storage may be associated with concentration effects resulting from moisture loss rather than actual mineral synthesis. The iron content observed in the present study was comparable with earlier reports, although some variations may be attributed to differences in genotype, growing environment and analytical procedures.

Phenolic compounds are important plant constituents that possess redox properties and act as powerful antioxidants. Wild fruits contain higher amounts of phenolic compounds than most cultivated species. During the storage period the phenolic

compound was found to decreased. This reduction may be attributed to enzymatic oxidation of phenolic compounds by polyphenoloxidase and peroxidase during post-harvest metabolism (30). Phenolics possess strong redox properties and contribute significantly to antioxidant potential; therefore, their decline during storage may indicate gradual reduction in antioxidant capacity. Similar findings have been reported in ber and other wild fruits, where prolonged storage resulted in a reduction of total phenolic content.

Overall, the present findings suggest that ambient storage induced significant biochemical and nutritional changes in *Z. oenopolia* fruits through carbohydrate hydrolysis, moisture loss, organic acid metabolism and antioxidant modulation, thereby influenced fruit quality, sweetness and nutritional composition.

## Conclusion

*Ziziphus oenopolia* (L.) Mill. an important underutilised wild fruit species widely distributed across agro-climatic regions of Odisha, served as a valuable source of nutrients and natural antioxidants for tribal and rural communities. Fruits collected from Bhawanipatna, Kamthana and Bharatpur were evaluated for physico-chemical, biochemical and nutritional attributes under ambient storage to assess germplasm variability and identify superior genotypes. During ripening and storage, total soluble solids (TSS), total sugars and total soluble carbohydrates (TSC) increased progressively, while titratable acidity and ascorbic acid declined. Potassium (K), phosphorus, iron and phenolic compounds exhibited noticeable variation among germplasms and storage periods, indicating significant genetic and biochemical diversity. The study provides baseline data on post-harvest physiology, biochemical behaviour and nutritional profiling of this underexplored species, highlighting variability for identification of superior genotypes for crop improvement. Fruits harvested at full ripeness and consumed fresh or after short-term storage possessed desirable sweetness, nutritional quality and antioxidant potential, suitable for fresh consumption and value-added products like beverages, processed foods and nutraceuticals. The observed genetic variability and nutritional richness indicated the scope for conservation, selective breeding, domestication and commercial cultivation, which contributed to sustainable horticultural development, nutritional security and livelihood enhancement in tribal and rural Odisha.

## Acknowledgements

The research work had been carried out in the laboratory of Department of Fruit Science, Institute of Agricultural Sciences, Siksha 'O' Anusandhan Deemed To be University, Bhubaneswar 751 003, Odisha, India. The authors are grateful for the facilities provided by the authority.

## Authors' contributions

ND and GM designed the concept of the study. ND has collected the fruit sample and conducted the experiment. GM and NJ have guided during the experiment. SM helped in preparation of manuscript. SKS, DAN, SM and SP helped in data analysis and finalised the manuscript. SM helped in modifications and coordination. All the authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

## References

- Reddy AGK, Kumar JS, Maruthi V, Venkatasubbaiah K, Rao CS. Fruit production under climate changing scenario in India: A review. *Environ Ecol*. 2017;35(2B):1010–7.
- Gupta OP, Kainsa RL, Chauhan KS. Post harvest studies on ber fruits (*Ziziphus mauritiana* Lamk.). I. Preparation of candy. *Haryana Agric Univ J Res*. 1980;10:163. <https://krishikosh.egranth.ac.in>
- Gupta OP, Kainsa RL, Chauhan KS, Dhawan SS. Post harvest studies in ber fruits (*Ziziphus mauritiana* Lamk.). IV. Comparison of sugar and gur for the preparation of candies. *Haryana Agric Univ J Res*. 1981;11:369–92.
- Gupta OP, Kainsa RL, Dhawan SS. Postharvest studies in ber fruits (*Ziziphus mauritiana* Lamk.). II. Evaluation of cultivars for candy making. *Haryana Agric Univ J Res*. 1981;11:480–92.
- Gupta AK, Panwar HS, Vashishtha BB. Studies on physico-chemical changes during development and maturity in ber fruit cv. Gola. *Punjab Hortic J*. 1983;23:186–90.
- Kumar S, Ojha CM, Bhagwan D, Awasthi OP, Nainwal NC. Potentiality of ber (*Ziziphus mauritiana* Lamk.) cultivars for candy making. *Prog Hortic*. 1992;24:74–8.
- Tiwari RJ, Banafar RNS. Studies on the nutritive constituents, yield and yield attributing characters in some ber (*Ziziphus jujuba*) genotypes. *Indian J Plant Physiol*. 1995;38:88–9.
- Pareek OP. The ber. New Delhi: Indian Council of Agricultural Research; 1983.
- Abbas MF, Al-Niami JH, Al-Ami RF. Some physiological characteristics of fruits of jujube (*Ziziphus spina-christi* L. Wild.) at different stages of maturity. *J Hortic Sci*. 1988;63:337–9. <https://doi.org/10.1080/14620316.1988.11515867>
- Pareek S, Fageria MS, Dhaka RS. Performance of ber genotypes under arid condition. *Curr Agric*. 2002;26:63–5.
- Bal JS. A note on sugars and amino acids in ripe ber. *Prog Hortic*. 1981;13:41–2.
- Arnon DI. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol*. 1949;24(1):1-15. <https://doi.org/10.1104/pp.24.1.1>
- AOAC. Official methods of analysis. Washington (DC): Association of Official Analytical Chemists; 1986.
- Ranganna S, Laxminarayan S. Non enzymatic discolouration in dried cabbage, ascorbic acid-amino acid interactions. *J Agric Food Chem*. 1968;16:529–33. <https://doi.org/10.1021/jf60157a013>
- Rangana S. Handbook of analysis and quality control for fruit and vegetable products. New Delhi: Tata McGraw-Hill Publishing Co. Ltd.; 1986. p.190–210.
- Swain T, Hills WE. The phenolic constituents of *Prunus domestica* L. The quantitative analysis of phenolic compounds. *J Sci Food Agric*. 1959;10:63–8. <https://doi.org/10.1002/jsfa.2740100110>
- Basak UC, Das AB, Das P. Chlorophyll, carotenoids, protein and secondary metabolites in leaves of 14 species of mangroves. *Bull Mar Sci*. 1996;58:654–9.
- Tamboli FA, More HN, Bhandugare SS, Patil AS, Jadhav NR, Killedar SG, et al. Estimation of total carbohydrate content by phenol sulphuric acid method from *Eichhornia crassipes* (Mart.) Solms. *Asian J Res Chem*. 2020;13(5):357–9. <https://doi.org/10.5958/0974-4150.2020.00067.X>

19. Rangana S. Handbook of analysis and quality control for fruit and vegetable products. 2<sup>nd</sup> ed. 10<sup>th</sup> reprint. New Delhi: Tata McGraw-Hill Publishing Company Ltd.; 2003.
20. Lindsay WL, Norwell WA. Development of a DTPA soil test for Zn, Fe, Mn and Cu. Soil Sci Soc Am J. 1978;42:421–8. <https://doi.org/10.2136/sssaj1978.03615995004200030009x>
21. Jackson RD, Kimball BA, Reginato RJ, Nakayama FS. Diurnal soil-water evaporation: Time-depth-flux patterns. Soil Sci Soc Am J. 1973;37(4):505–9. <https://doi.org/10.2136/sssaj1973.03615995003700040014x>
22. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 4<sup>th</sup> ed. New Delhi: Indian Council of Agricultural Research; 1989. p. 359.
23. Mahajan BVC, Dhillon SB. Evaluation of different cultivars of litchi (*Litchi chinensis* Sonn.) under sub-mountainous regions of Punjab. Haryana J Hort Sci. 2000;29:184.
24. Mishra G. Genetic evaluation of wild pomegranate germplasm for various pomological traits [MSc thesis]. Nauni (Solan): Dr. YS Parmar University of Horticulture and Forestry; 2015.
25. Salunkhe DK, Desai BB. Postharvest biotechnology of fruit. Boca Raton (FL): CRC Press; 1984.
26. Stahl AC, Camp AF. Citrus fruits. In: Hulme AC, editor. The biochemistry of fruits and their products. Vol. 2. London: Academic Press; 1971. p.107–69.
27. Jawanda JS, Bal JS. A comparative study on growth and development of ZG-2 and Kaithli cultivars of ber. Punjab Hortic J. 1980;20:41–6.
28. Devi P, Gautam RKS, Singh J, Maurya SK, Chaudhary A. Effect of foliar application of NAA, GA<sub>3</sub> and zinc sulphate on fruit drop, growth and yield of ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka. Int J Curr Microbiol Appl Sci. 2019;8(1):1679–83. <https://doi.org/10.20546/ijcmas.2019.801.177>
29. Mahapatra AK, Panda CP. Wild edible fruit diversity and its significance in the livelihood of indigenous tribals: Evidence from eastern India. Food Secur. 2012;4(2):219–34. <https://doi.org/10.1007/s12571-012-0186-z>
30. Deng M, Deng Y, Deng Y, Lei L, Wei LM, Zhang FZ, et al. Effect of storage conditions on phenolic profiles and antioxidant activity of litchi pericarp. Molecules. 2018;23(9):2276. <https://doi.org/10.3390/molecules23092276>

#### Additional information

**Peer review:** Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

**Reprints & permissions information** is available at [https://horizonpublishing.com/journals/index.php/PST/open\\_access\\_policy](https://horizonpublishing.com/journals/index.php/PST/open_access_policy)

**Publisher's Note:** Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Indexing:** Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See [https://horizonpublishing.com/journals/index.php/PST/indexing\\_abstracting](https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting)

**Copyright:** © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

**Publisher information:** Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.