

## Impact of Drying Methods on the Quality of Bioactive Components in Tree Tomato (*Cyphomandra betacea*)

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### Abstract

Tamarillo (*Cyphomandra betacea*) is a tree native to Peru and is cultivated in few areas of Western and Eastern Ghats in India. It has high nutritive and therapeutic value due to the abundance of health promoting substances. Owing to its high nutritive profile, a study was conducted to examine the nutritional composition of fresh fruits and dried fruit powder. Fresh Tamarillo was dried under different methods of drying (sun drying, cabinet/tray drying and freeze drying). The dried samples were made into powder and used for comparative analysis of various bioactive constituents and antioxidants (antioxidant activity, total phenols, carotene, vitamin C, colour value, elemental analysis). From the results it was observed that the samples dried under freeze dried condition exhibited better antioxidant activity (13.82 mg/g), carotene (15.97 mg/100 g), vitamin C content (217.1 mg/100 g) than that of the samples dried under sun drying and cabinet tray drying. This might be due to long exposure time and leaching effect of the tamarillo samples to air. Among the three drying methods, sun drying resulted in significant micronutrient loss and exhibited low antioxidant activity due to the use of uncontrolled temperature during drying process. This underutilized fruit is consumed in the fresh form as it is a seasonal fruit. Converting the seasonal fruit into dried or powder form will help in development of nutritive-rich food products.

**Keywords:** Tamarillo, Antioxidants, Carotene, Total phenols, Vitamin C, Freeze drying

### Introduction

Tamarillo or tree tomato (*Cyphomandra betacea*) belongs to Solanaceae family. It bears an egg shaped fruit with a radius of about 4.5 to 6 cm and the colour varies based on the maturity of the fruit [1]. The skin colour of tree tomato varies from yellow, orange to red and almost in purple also. The fruit colour is mainly determined by the presence of pigments like anthocyanins which imparts red colour and carotenoids are responsible for the yellow-orange colour [2]. Peel of the fruit is not recommended for consumption. The fleshy edible part is firm and contains more seeds and the seeds are covered by purple or red mucilage [3]. The existence of assortment in the fruits exhibits different chemical composition amongst varieties. The presence of carotenoids and anthocyanin promote its therapeutic, biological and preventive characteristics [4].

The fruit contains less fat and has low calorific value. It supplies dietary fibers, minerals such as phosphorus, potassium, calcium, magnesium, iron, copper and zinc, vitamins such as B6, C and E, proteins, soluble sugars (glucose, fructose and sucrose) and also few organic acids namely citric and malic acids [2,5-7]. It also contains a mixture of phytochemicals which has essential nutritional and pharmacological components such as non-starch polysaccharides (pectin), flavonoids, carotenoids [3]. Due to diversity in composition, each part of the fruit exhibits different nutritional profile. It was reported that the seeds of tamarillo contain lipids such as  $\omega$  - 3, 6 and 9 fatty acids, vitamin E,

polyphenols, proteins, minerals, and phytosterols viz., sitosterol, cycloartenol and dihydrolanosterol [8]. It has been proclaimed that *Cyphomandra betacea* is rich in  $\beta$ -carotene and ascorbic acid that made them predominant because of the presence of vitamin A and vitamin C. Tamarillo has high source of anthocyanin and carotenoids which gives natural pigmentation for the fruit and have extensive biological, therapeutic and preventive properties [9,10].

The diverse biological activities and novel eating habits, paved way for the development of a variety of tamarillo based products (salads, sauces, jellies, ice creams, juices, liqueurs, yogurts and fruit effervescent tablets) [2,11]. Functional ingredients derived from tamarillo find more applications in food industries. It is used as a coagulant in dairy industry for making natural cheese, as an antioxidant additive in the meat industry and also as an emulsifier and foam stabilizer in a variety of food applications [12,13]. Few authors have also reported about the non-food applications of tamarillo [14]. But the availability of information about the phytochemical profiles of antioxidant and anticancer potential of tamarillo is comparatively less. It has been reported that the crude extract of tamarillo have anti-proliferative activity against cancer cell lines.

The phenolic acids and flavonoids profiling by HPLC-DAD-MS method has identified some of the major polyphenols which are likely to contribute to the chemo preventive activity. It has also shown high antioxidant activity due to the presence of polyphenolic, flavonols and anthocyanins compounds. Flavonoids exhibit an antibacterial and antiproliferative activities with minimum inhibitory concentrations [15]. It has exceptionally broad range of antioxidant and anticancer properties and has excellent potential for the development of functional food products and nutraceutical formulations [16]. Acetous products had become one of the important sub-sector of food industry which uses modern drying methods in addition to traditional sun drying methods.

Keeping the potential health benefits and biological activities of tree tomato, a research was performed to explore the nutritional composition of tamarillo fruits dried under different conditions (sun drying, cabinet/tray drying and freeze drying) and to compare the nutritional composition and antioxidant components of the samples.

## Materials and methods

### Raw materials

Tamarillo (tree tomato) fruits were purchased from a local market in Nilgiris district, located in the Western Ghats of Tamil Nadu, India. Tamarillos which have reached horticulture (commercial) maturity at 21 to 24 weeks after anthesis. The attainment of full red or yellow colour is the primary maturity index. The fruits were selected based on uniform maturity, colour and size. The samples were cleaned with water and stored at refrigerated condition until further analysis.

### Reagents and chemicals

The reagents and chemicals such as Petroleum ether (68 % v/v), ethanol, sodium hydroxide, sodium sulphate, copper sulphate, boric acid, sulphuric acid,  $\alpha$ -amylase, protease, amyloglucosidase, glucose, sulphuric acid, Phenol, sodium phosphate buffer, potassium ferricyanide, trichloroacetic acid, Folin-Ciocalteu reagent, sodium carbonate, cyclohexane, meta-phosphoric acid, indophenol dye, standard ascorbic acid, nitric acid, hydrogen peroxide, hydrogen fluoride, standards of magnesium, phosphate, calcium, potassium were procured from the precision scientific company, Coimbatore, Tamil Nadu, India.

### Drying methods

The following 3 types of drying methods were adopted for drying the tree tomato samples.

**Sun drying:** About 250 g of samples were cut into thin slices (1 cm thickness) and were spread as thin layer on a tray of size 36 $\times$ 18 cm<sup>2</sup> and dried under sunlight at a temperature of about 30 to 32 °C and around 65 % Relative Humidity (RH). The samples were dried for about 2.5 days and were then powdered for further analysis.

**Cabinet/tray drying:** About 250 g of cut samples were spread on a tray of same size as mentioned above as thin layer and dried in a cabinet dryer at a temperature of about 60 °C for about 8 h till constant weight was attained [17]. The samples were powdered and analyzed.

**Freeze drying:** Fruits of about 250 g were cut into thin slices and pre frozen in a refrigerator for 8 h and then freeze dried in lyophilizer for 48 h. The freeze dried sample in the powder form was used for analysis [18].

### **Sample preparation for nutritional analysis**

The nutritional analysis of raw samples was done for 12 fruits. The fruits were initially kept in boiling water for 2 min in order to remove the skin and made into pulp for analyzing nutritional composition. About 0.5 g of each batch of dried tree tomato powder were extracted with 20 mL of 60 % ethanol in a sealed flask and kept in a water bath for 4 h at 70 °C. After 4 h, once the extraction process was done, the extracts were centrifuged in a laboratory centrifuge (10,000 rpm) for 10 min. The supernatant was collected and then stored for further analysis [19].

### **Determination of chemical composition**

#### ***Estimation of moisture content***

To assess the moisture content of the sample, 3 sets of 5 g of tree tomato pulp were taken in petri plates and kept in hot air oven at a temperature of 100 °C. The samples were weighed at a time interval of 20 min until constant weight was obtained. Once the samples were taken from oven, they were kept in a desiccator to avoid further dehydration [17].

#### ***Estimation of protein***

The micro kjeldahl method is based on the same principle of macro kjeldahl method but the apparatus used is scaled down [20]. About 1 g of tree tomato pulp was taken for nitrogen analysis. The sample was then digested for 4 h for the conversion of amine groups to ammonium sulphate. After digestion it was neutralized along with the release of ammonium gas and then finally titrated against 1N HCl [21]. The final results were multiplied by 6.25 to estimate the protein content.

#### ***Estimation of dietary fibre***

The estimation of total dietary fibre was done based AACC method. The sample was enzymatically digested by heat stable  $\alpha$ -amylase, protease, and amyloglucosidase. About 1 g of dried tamarillo sample was subjected to enzymatic digestion by heat stable  $\alpha$ -amylase and incubated at 60 with protease and amyloglucosidase. Then, the samples were precipitated by treating it with ethanol. The soluble fibre was precipitated in order to remove depolymerised protein and glucose. The residue was filtered, washed with 95 % ethanol and acetone, dried and weighed. The weight of the filter determines the total dietary fibre [22].

#### **Determination of crude fat**

To extract fat from tree tomato, Soxhlet extraction was used. Sample 5 g of dried tree tomato was taken and kept for extraction. About 50 mL of Petroleum ether was poured into 100 mL round bottom flask and the apparatus was kept for extraction. After 6 h of extraction the round bottom flask was removed and then heated in water bath to remove the excess water. The solvent was removed and the extracted fat was weighed. The fat content of the sample was calculated.

#### **Determination of ash content**

Tree tomato pulp weighing 5 g was taken in crucible and it was placed in muffle furnace at 600 °C for a minimum of 6 h. Remove the crucible from the furnace once it is completely cooled and then directly place in the desiccators to avoid further dehydration. The crucible was weighed before and after placing in the muffle furnace [23]. The experiment was triplicated to obtain mean value.

#### **Estimation of total sugars**

The total sugar content of the samples dried under sun drying, cabinet/tray drying and freeze drying was estimated using the standard procedure. About 1 g of each samples were mixed in 10 mL of distilled water. Working standard of glucose of different volumes 0.2, 0.4, 0.6, 0.8 and 1 mL of were taken in boiling tubes and finally made up to 1 mL distilled water. In blank, 1 mL of distilled water was added instead of working standard solution in sample test tubes 0.2 mL of samples were taken. 1 mL of 5 % and 5 mL of 96 % sulphuric acid was added one by one in each tubes and shook well so that the phenol and sulphuric acid get mixed thoroughly with working standard. After addition of chemicals, all the test tubes were placed in water bath 25 - 35 °C for 15 min. The readings were taken at 490 nm with spectrophotometer [24].

### Determination of elemental composition

Elemental analysis of the 3 samples was done using ICP- ES (Inductively coupled plasma - optical emission spectrometry). The sample was prepared using acid digestion method before injecting into the instrument for carrying out elemental composition analysis.

### Quantification of antioxidants and total phenols

#### Determination of antioxidant activity (FRAP) assay

Antioxidant activity was measured using FRAP assay. Different concentrations of sun dried, tray dried and freeze dried tamarillo extracts were taken. In each of the extracts 2.5 mL of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 mL of 1 % potassium ferricyanide ( $K_3[Fe(CN)_6]$ ) solution were added. The samples were vortexed and incubated at 50 °C for 20 min. After incubation, 2.5 mL of 10 % trichloroacetic acid was added and mixed well. The samples were subjected to centrifugation for 10 min at 3,000 rpm. From the centrifuged sample, about 2.5 mL of supernatant was taken and mixed with 2.5 mL of deionised water and 0.5 mL of 0.1 % ferric chloride. The absorbance at 700 nm using UV Spectrophotometer was read [25].

#### Determination of total phenolic content

Total phenolic content of the samples was estimated by Folin-Ciocalteu's method. Approximately 200  $\mu$ L of crude extract (1 mg/mL) were made upto 3 mL with distilled water and then mixed well with 0.5 mL of Folin-Ciocalteu reagent for 5 min. After 5 min, 2 mL of 20 % (w/v) sodium carbonate was added. The samples were then incubated for 60 min in cool, dark place. The absorbance was read at 650 nm [26].

#### Determination of carotenoid content

Weighed about 1mg of each of the samples. Added them into a 100 mL volumetric flask, dissolved them with cyclohexane and made up to the volume. Filled the cuvette with the sample solution and matched it with a cuvette containing cyclohexane. Read the absorbance at 445nm in spectrophotometer [27].

$$\text{Carotene content (mg / kg (ppm) as beta carotene)} = \frac{383 E}{t c}$$

where, E = Observed difference in absorption between sample solution and cyclohexane,  
t = path length of the cell,  
c = concentration used for absorption measurement.

#### Estimation of vitamin C

Vitamin C is an important nutrient in the diet but it is easily reduced by exposure to heat and oxygen. Vitamin C was determined by oxidising it in acidic media with 2, 6-Dichlorophenol indophenol. Sun dried, cabinet/tray dried and freeze dried samples were diluted in 10 mL of distilled water. Then, 10 mL of metaphosphoric acid was added to the sample which is kept in Erlenmeyer Flask and titrated it against indophenol dye solution until a faint red colour appeared. Vitamin C content was calculated in mg/100 g of the sample in comparison with standard ascorbic acid [28].

#### Determination of colour value

Tree tomato has higher level of solids, in order to keep the degree of translucency relatively even. The samples were diluted to a level of 8.5 °brix. The colour of the samples was measured by Lovibond instrument, by its colour disk samples which have been classified based on colour categories. Image information of the colour is generally determined using a combination of Red, Green, Blue (R, G, B) values and transforming this colour information into a single hue buffer helps to determine the colour easier.

$$G < B, \quad H = \frac{1}{360^\circ} \left[ 90^\circ - \tan^{-1} \frac{F}{\sqrt{3}} + 0^\circ \right]$$

$$G > B, \quad H = \frac{1}{360^\circ} \left[ 90^\circ - \tan^{-1} \frac{F}{\sqrt{3}} + 180^\circ \right]$$

where,  $F = (2 \times R - G - B) / (G - B)$

A combination of Lovibond glasses were usually used to construct models in between calorimeter and image analysis. A red reading of each glass predicts the least and hue values of the corresponding capture image were negative. Lovibond red value of the image analysis method can be obtained by the following model [29].

$$\text{Log (automatic Lovibond red reading)} = a - b \times \text{Hue}$$

## Results and discussion

Tree tomato or tamarillo is regarded as cancer fruit by the researchers because of its abundant antioxidant property. The analysis of the nutritional composition and antioxidant activity of the samples prepared under different drying methods are reported.

### Nutritional composition

The detailed report of the nutritional analysis of tree tomato is listed in **Table 1**. It is observed from the table that Tamarillo fruit (pulp) has a moisture content of about 87 %. Protein content, total fat, ash content and total sugar content is reported as 1.7, 0.42 and 0.4 g/100 g of sample, respectively. These values are in line with the values obtained by Mutalib *et al.* [4]. The total sugar content of the sample tested was 21.81 g/100 g, and similar to the results reported by Acosta-Quezada *et al.* [2]. Tamarillo fruits have comparatively low amount of total fat (0.42 g/100 g) and this value is well supported by the findings of Vasco *et al.* [30]. The variation in the results is due to changes in the cultivars, geographical location, etc.

**Table 1** Proximate composition of Tamarillo.

Parameter	Units	Composition (per 100 g)
Moisture	%	87 ± 0.8
Protein	g	1.7 ± 0.23
Total fat	g	0.42 ± 0.75
Crude fat	g	3.0 ± 0.92
Ash	g	0.4 ± 0.68
Total sugars	g	21.81 ± 1.23

### Elemental composition

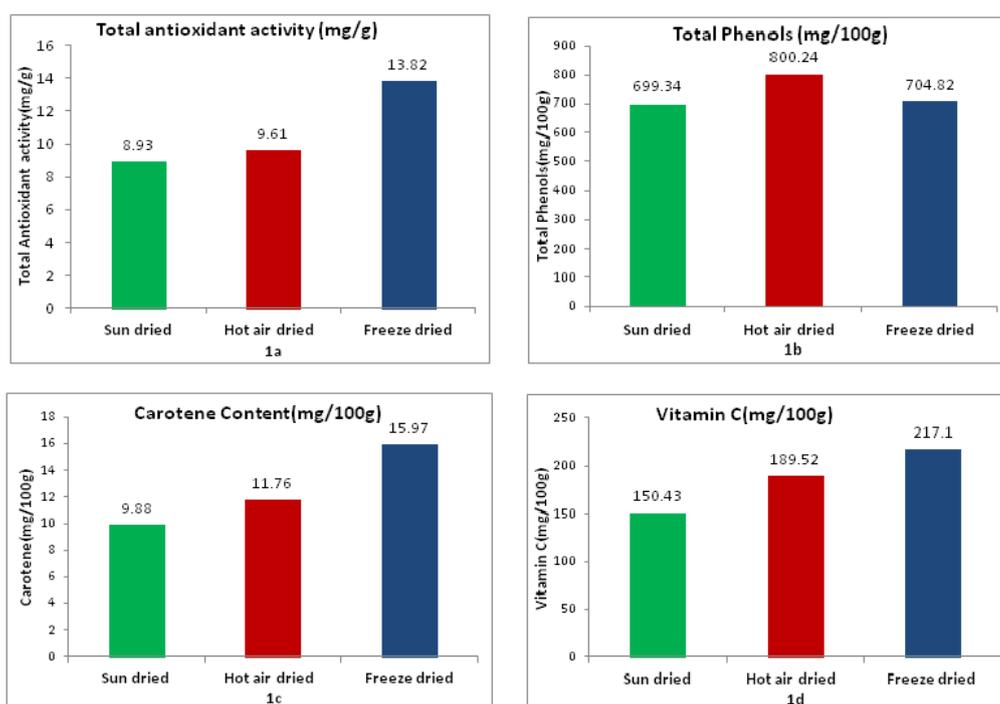
The amount of mineral content present in the 3 types of samples dried using different methods is provided in **Table 2**. From the results it was observed that the mineral content of the samples ranged from 10.58 to 12.7, 33.9 to 35.6, 18.78 to 24.1, 338 to 374 and 0.43 to 0.61 g/100 g of samples by dry weight, for calcium, phosphorous, magnesium, potassium and sodium, respectively. It was found that potassium content is high in all the samples whereas sodium is very low. Tamarillo fruit is a potential source of potassium [31]. Potassium is a highly needed compound for human system as they are essential for proper functioning of cells. Calcium is considered to be the building blocks of bones and teeth and tamarillo has considerable amount of calcium. The tamarillo powdered samples are high in potassium but extremely low in sodium, which is a desirable balance for a healthy diet [18]. Due to low sodium content, the tamarillo fruit has been regarded as defensive factor against cardiovascular diseases. From the nutritional point, it can be used as a dietary food supplement, since it will not increase the mineral content of food considerably, by providing low amount of sodium. The values of mineral compositions are similar to the results of Vasco *et al.* [30] for the tree tomato variety from Spain. Climatic conditions, variety, origin and cultivation methods also influenced the mineral composition of the tamarillo fruits [2,4,30].

In general, the results showed that the mineral present are retained high in sample which has undergone freeze drying process except phosphorous (high in hot air dried sample). This might be mainly due to the retention of more solutes in the foods by freezing the water molecules in to ice crystals. Jenny *et al.* [32] analyzed the proximate and nutritional composition of sea weed using different drying methods and reported that sun dried sea weed had the lowest values of ash content, mineral and total vitamin Contents. It was also reported that the lowest values were due to the leaching

effect and long exposure time to air during drying. The current experimental results are in line with the results obtained by Jenny *et al.* [32].

**Table 2** Elemental analysis of tree tomato samples dried at different drying conditions.

Element	Sun dried (mg)	Hot air dried (mg)	Freeze dried (mg)
Calcium	10.58 ± 0.38	11.3 ± 0.76	12.7 ± 0.32
Phosphorus	34.20 ± 0.43	35.6 ± 0.45	33.9 ± 0.61
Magnesium	18.78 ± 0.98	19.6 ± 0.36	24.1 ± 0.82
Potassium	338.0 ± 0.56	342 ± 0.62	374 ± 0.97
sodium	0.43 ± 0.32	0.51 ± 0.59	0.61 ± 0.19



**Figure 1** Antioxidant components of the samples dried using different methods.

### Antioxidant composition

Anti-oxidants are substances that inhibit or delay the oxidation of biologically relevant molecules. Antioxidant components include phenolic, polyphenolic compounds, vitamins and carotenoids.

#### Total antioxidant activity

Many researchers have extensively studied the *in vitro* antioxidant activities of tamarillo fruits using chemical and cell based assays [6]. Many chemical assays are in vogue to find out the antioxidant activity. In the current study, ferric reducing antioxidant power (FRAP) was used and presented in the **Figure 1a**. All the 3 samples exhibited a wide spectrum of antioxidant activities. Sun dried samples showed a lower activity (8.93 mg/g) when compared to tray dried and freeze dried samples (9.61 and 13.82 mg/g). The highest antioxidant activity was shown by freeze dried sample (13.82 mg/g). An increased total antioxidant capacity of freeze-dried fruits was reported for guabiju, red guava [33]. This might be due to the fact that freeze drying uses low temperature which retains heat sensitive phytochemicals than hot air and sun drying [34].

#### Total phenolic content

From the results, it was observed that the total phenolic content of all the 3 samples ranged from 699.34 to 800.24 mg/100 g (**Figure 1b**). Among the samples, cabinet/tray dried sample reported the

highest value than their counter parts (freeze dried and sun dried samples). The presence of low phenolic content in the sun-dried sample might be due to the activation of oxidative enzymes viz., polyphenol oxidase and peroxidase and also binding of phenolic compounds to proteins, might have resulted in alteration in chemical structures or reduction in the efficiency of extraction [35]. The occurrence of higher phenolic content in cabinet/tray dried sample might be due to rehydration and release of phenolic content from cell walls and rise in free hydroxy phenols [36].

#### Carotene content

Carotene is a type of carotenoids present in fruit and vegetables and have positive effect on body health and are considered as precursor for Vitamin A. It is evident from the **Figure 1c** that the Carotene content of all the 3 samples was 9.88, 11.76 and 15.97 mg/100 g and this value is higher than the values (2.6 to 11.2 mg/100 g) reported by Acosta- Quezada *et al.* [2]. This might be due to the variation in the cultivars and climatic conditions. The low carotene content in the sun dried and cabinet/tray dried samples might be due to degradation of carotenoids during drying because of high sensitivity to oxidation and increased porosity when exposed to hot conditions [37].

#### Vitamin C/ascorbic acid content

Vitamin C has vast function on antioxidant property and involves in the production of collagen. Ascorbic acid plays a key role in building the muscles, vascular tissues and also contributes to healthy teeth, iron absorption and to improve the immune system [18]. In the present study, high ascorbic acid content was observed for the sample dried under freeze drying (217.1 mg/100 g). The lower content was reported for cabinet/tray dried (189.52 mg/100 g) and sun dried (150.43 mg/100 g) samples (**Figure 1d**). The low value of ascorbic acid content in sun dried sample was due to the leaching effect and long exposure time to air during drying [32]. The loss of ascorbic acid during sun and hot air drying might be due to oxidation and the exploitation of the same for protecting polyphenols oxidation [38]. It was reported that tray drying cause higher loss of Vitamin C when compared to other techniques. It was found that a prolonged drying aid in quicker oxidation of ascorbic acid [39].

#### Colour value

The variation in the colour of all the 3 samples can be visualized by human eye, which is due to the combination hue, saturation and intensity. Hue value defines the wavelength of various colours like red, blue and green. Colour value of each sample has been defined by comparison with different hue values. As defined in GB5525-85 red colour of visual measurements have been used as a reference for the samples. Image analysis was done in comparison with 6 sets of standard glasses and the samples [29]. Colour value of all the samples is represented in **Table 3**. It is seen that the hue value of each sample shows a slight variation among the samples. The drying methods did not affect the colour of the dried samples to a larger extent.

**Table 3** Colour value of Tamarillo samples dried under different methods.

Parameters	Sun dried samples	Hot air dried samples	Freeze dried samples
L	74.81	74.51	73.98
A	1.54	1.32	2.94
B	10.78	12.06	10.23
dE	25.98	26.35	26.22
dL	-21.78	-22.36	-22.88

## Conclusions

Tamarillo is an underutilized fruit even though it possesses higher nutritional and therapeutic values. It has low fat content and is a source of carbohydrates, protein, vitamins and minerals, ascorbic acid, polyphenols and carotenoids. The extract of the fruits possesses a wide range of antioxidant activities such as anti-oxidation, anti-inflammation, anti-cancer, etc. The current study aimed to explore the nutritional profile and antioxidant activity of tamarillo available in the locality. The fruits were subjected to drying under various drying methods (sun drying, cabinet tray drying and freeze drying). Analysis of the powdered samples was done to estimate the antioxidant properties. From the results it was observed that the samples dried under freeze dried condition exhibited better antioxidant activity (13.82 mg/g), carotene (15.97 mg/100 g), vitamin C content (217.1 mg/100 g) than that of the samples dried under sun drying and cabinet tray drying. This might be due to long exposure time and leaching effect of the tamarillo samples to air. Among the 3 drying methods, sun drying resulted in significant micronutrient loss and exhibited low antioxidant activity due to the use of uncontrolled temperature during drying process. It is evident from the results that the tamarillo fruits could be a better source to develop antioxidant rich value-added products, nutraceuticals and bio colorant.

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