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Unlocking Tamarillo's Potential: Effect of Drying Methods on Bioactive Compounds of *Solanum betaceum* Cav.

Running title "Impact of Drying on Tamarillo Bioactives"

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Abstract

Background "Tamarillo" scientifically known as *Solanum betaceum* is an indigenous fruit grown predominantly in Southern parts of India. These fruits are rich in dietary fibre and other bioactive ingredients but often overlooked owing to their availability, lack of awareness etc.

Methodology Tamarillo fruits were collected from Nilgiris district, Tamil Nadu, India. Fruits were subjected to different drying methods and steamed. Further, fruits from best-dried method steamed and fresh fruit were analyzed for total phenols, flavonoids and glycosides. Juice and salsa were developed and evaluated for various parameters.

Results Compared to every drying method, Freeze-dried samples of whole fruit pulp and flesh were found to be statistically significant (P=0.020), (P = 0.005). Phenols, flavonoids and Glycosides of FDWP were found to be (56.4, 45.8, 16.2 mg/ 100ml) respectively. The overall mean and standard deviation of the nutritional content in sundried tamarillo exhibited SDWP (24.3+15.1), SDF (23.1+14.6) and SDP (20.5+8.9). Cabinet dried tamarillo exhibited CDWP (20.2+23.6), CDF (17.9+19.9), CDP (16.4+15.8). The freeze-dried tamarillo exhibited FDWP (40.6+5.02), FDF (33.5+4.03), FDS (49.5+21.8), FDJ (33.6+9.3) and FDP (31.0+10.2). A significant difference between tamarillo salsa and juice of P = <0.001 was observed.

Conclusion Freeze-drying best preserves tamarillo bioactive compounds and extends its availability beyond its season, making it more desirable as fresh juice or salsa.

Keywords Tamarillo, sensory attributes, freeze-drying, phenols, flavonoids, glycosides.

Highlights

- This study investigated the effects of various drying methods (sun drying, cabinet drying, and freeze-drying) on the nutritional content and bioactive compounds of tamarillo.
- Freeze-drying emerged as the most effective method for preserving overall nutritional value, it retained the highest levels of nutrients.
- Sun drying, while reducing moisture content, found to be the most suitable method for preserving minerals. Steaming, although effective in retaining phenolics and flavonoids (antioxidants), may not be practical for large-scale commercial purposes.
- Overall, this study provides valuable insights into preserving the nutritional and health benefits of tamarillo fruit through different drying techniques.

1. INTRODUCTION

According to WHO recommendations, daily consumption of over 400 grams of fruits and vegetables and limit the intake of fat, sugar and sodium can enhance the overall health and lower the risk of specific non-communicable diseases (WHO, 2023). Fruits and vegetables, rich in dietary fiber, vitamins, and minerals, especially high levels of phytochemicals, natural antioxidants and phenolic compounds significantly reduced the incidence of chronic diseases and considered to be responsible for chemo preventive effects (Ya Li *et al*., 2016). Tamarillo is a South American fruit gaining popularity worldwide for its unique flavour and nutritional value. The fruit is available in Tamil Nadu in India and other countries such as Indonesia, Bolivia, Peru etc., It is a rich source of vitamins, minerals, dietary fibre, and various bioactive compounds with potential health benefits, including antioxidant, anti-inflammatory, and anticancer properties (Ya Li *et al*., 2016). These impacts on health have been provisionally correlated to specific phytochemicals (Sunan *et al*., 2020). This study highlighted the potential of indigenous fruit in the prevention and treatment of certain chronic diseases. The drying methods used for dehydrating the fruits, nutritional content and bioactive components namely phenols, flavonoids and glycosides and health advantages are offered by tamarillo fruit. The process of drying fruit is one of the oldest methods of food preservation. Dried fruits and vegetables offer high levels of fibre and carbohydrates while being low in fat, rendering them nourishing food options. (Ahmed *et al*., 2013).

2. METHODS AND MATERIALS

2.1. Sample procurement and authentication

Tamarillo fruits were collected from Gudalur, a hilly region, Nilgiris District of Tamil Nadu, India, were chosen for analysis. The fruits were selected on the basis of maturity and fully ripened state. They were then stored in refrigeration for future use as it ensures their freshness and viability for further examination. The authenticity and certification of the Tamarillo fruit were confirmed at the Botanical Survey of India at TNAU in Coimbatore, India.

2.2. Sample preparation

The fruits underwent a process of washing, cutting, and then segregated into the following categories of: Fresh (F), steamed (S) fruits, Freeze-dried whole pulp (FDWP), Freeze-dried flesh (FDF), Freeze-dried salsa (FDS), Freeze-dried juice (FDJ) and Freeze-dried peel (FDP). Sun drying fruits were divided into Sun-dried whole pulp (SDWP), Sun-dried flesh (SDF), Sun dried peel (SDP). Cabinet dried fruits were split into Cabinet dried whole pulp (CDWP), Cabinet dried flesh (CDF), Cabinet dried pulp (CDP). A quantity of 250 grams of fruits were utilized for each sampling before undergoing drying.

2.3. Drying techniques

For each sample and every drying method, 250 grams of fruit were utilized. Sun drying refers to the process of dehydrating food products using natural sunlight. No energy is required for this type of drying. Ideal conditions for sun drying include hot days with temperatures exceeding 35°C and low humidity levels. To attain high-quality dried products, it is essential to start with good-quality produce. Typically, a moisture content of around 15 percent is the lower limit achievable through this method. Some fruits were sundried at 30° C and 86° F for 3 days. Foods, both in solid pieces and liquids, underwent drying through freeze-drying. Samples were subjected to temperatures ranging from -45°C to -50°C during the drying process. The material was first frozen on trays and then dried under vacuum conditions. Vacuum drying facilitates direct drying of the material without transitioning through the intermediate liquid phase. The underlying principle of freeze-drying lies in specific conditions of low vapor pressure. Cabinet dryers were employed for the dehydration of solid food items. Fruits also underwent cabinet drying at the temperature of 65° C. Then the samples were ground to powder form post drying.

2.4. Sensory attributes of developed food from tamarillo

Salas was prepared by added onion, garlic, red chilli and salt and juice was developed by fruit pulp mixed with water, salsa and juice picture was given in Figure 1. To assess consumer preference, sensory evaluation was conducted in a specialized sensory evaluation center at Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. The center is equipped with five individual booths, each with colored lighting to prevent visual bias based on food color. Thirty Semi trained panel participants, including research students and faculty from Food Science and Nutrition department were recruited. They evaluated both tamarillo salsa and juice based on appearance, color, texture, flavor, taste, and overall liking using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely). Each participant evaluated the samples individually. Fresh samples were prepared for each participant to ensure consistency. Scorecards were provided, allowing participants to rate each attribute on a scale of 1 to 9. Statistical analysis was performed using the SigmaPlot software package. One-way analysis of variance (ANOVA) was used to analyze the data.

Figure 1. Tamarillo Juice and Salsa

Tamarillo Juice Tamarillo Salsa

2.5. Proximate and nutrient analysis

The nutritional composition of Tamarillo was analyzed in triplicate samples using standard procedures recommended by AOAC methods. The moisture content was determined using a preheated hot air oven set at 110° C. Ash content was measured by ashing five grams of the sample in an electronic muffle furnace at temperatures ranging from 500° C to 600° C. Protein content was assessed through the Kjeldahl method, which measures the nitrogen content in the sample (Nallakurumban *et al*., 2015). The energy value was calculated using a bomb calorimeter (Azizi *et al*., 2021). Carbohydrates were determined using the Anthrone method, while dietary fiber was estimated using an enzymatic method. Vitamin C content was assessed using the dye method by reducing 2,6 dichlorophenol indophenol acid solution. Carotene was extracted from the sample using petroleum ether, and its concentration was compared to a standard solution using a calorimeter. Calcium content was determined using the dye method with potassium permanganate. Iron and phosphorus contents were estimated using colorimetric methods.

2.6. Determination of total phenolic content

The quantification of total phenolic content involved using the Folin Ciocalteau reagent, where 200 µl of the sample was added to a 25ml volumetric flask. After a 5-minute incubation period, 4ml of 20% sodium carbonate solution was added, and the volume was adjusted to 25 ml with water. This mixture was allowed to stand for 30 minutes until a blue colouration developed. Subsequently, readings were taken using a UV spectrophotometer at 765nm, and the results were reported as gallic acid equivalents.

2.7. Determination of total flavonoid content

The flavonoid content was assessed through the aluminium chloride colorimetric method. 1 ml of sample extract and standard catechin solution was taken separately in 10 ml volumetric flasks, and then combined with 4 ml of distilled water. Subsequently, 0.3 ml of 5% NaNO2 was added, followed by the addition of 0.3 ml of 10% AlCl3 after 5 minutes. At the 6th minute mark, 2 ml of 1 M NaOH was added, and the total volume was adjusted to 10 ml with distilled water. After thorough mixing, the absorbance was measured at 510 nm against a prepared reagent blank.

2.8. Glycoside estimation

The glycoside content was determined using Baljet's reagent, which comprised of 95ml of 1% picric acid and 5 ml of 10% NaOH, along with 2g of the sample and a standard of securidaside. Following this, the mixture was diluted with 20 ml of water, and the absorbance was measured at 495 nm using a UV/VIS spectrophotometer.

Statistical analysis

All analyses were performed in triplicate, and data were subjected to statistical analysis with Tukey test under (RMANOVA) and ANOVA to determine significant differences (> 0.020 and >0.005) between different processing methods using Sigmaplot software 14.5 and then mean, standard deviation were also calculated.

3. RESULTS AND DISCUSSION

3.1.Sensory Attributes of Tamarillo salsa and juice

Sensory attributes	Tamarillo salsa Mean± SD	Tamarillo juice Mean± SD	p value
Appearance	8.23±0.72	8.53±0.50	P = <0.001
Color	8.10±0.71	8.50±0.50	
Texture/Consistency	8.23±0.67	8.50±0.50	
Flavor	7.66±0.71	7.73±0.45	
Taste	8.26±0.44	7.70±0.46	
Overall Acceptability	7.63±0.55	7.93±0.45	

P = <0.001 indicates there is statistically significant difference between tamarillo salsa and juice

Table 1 summarized the results of the hedonic evaluation. Scores were averaged (mean) and variability was measured (standard deviation) for the 30 participants. As expected, the 9-point hedonic scale effectively measured consumer preference and provided reliable data. Interestingly, there was a significant difference in overall liking between the salsa and juice. Both scored moderately well, with the salsa at 7.6 ± 0.55 and the juice at 7.9 ± 0.4 (on a scale of 1=dislike extremely to 9=like extremely according to Syu *et al.*, 2023). However, when looking at individual characteristics, some differences emerged. Appearance, color, and texture/consistency were rated similarly for both products (around 8.2-8.5). Flavor and taste scores were slightly lower for the salsa (7.3 and 7.6) compared to the juice (7.7 and 8.2). This suggested that though both products were generally liked moderately, the juice might have had a slight edge in terms of flavor and taste.

3.2. Proximate and nutrient content of Sun dried, Cabinet dried and Freeze-dried whole pulp of Tamarillo fruit

Nutrients(100g)	**SDWP**	**CDWP**	**FDWP**
Ash (g)	85± 5	88.33± 11.54	**97.36±1.18**
Moisture (%)	71.73 ± 2.83	84.63 ± 2.85	**86.36 ± 1.88**
Energy(kcal)	35	36.9	37.1
Carbohydrate (g)	6.5 ± 0.2	6.63 ± 0.37	7.76 ± 0.15
Protein (g)	1.1 ± 0.1	0.74 ±0.02	**1.30 ± 0.19**
Fat (g)	0.37 ±0.02	0.42 ±0.01	0.42 ±0.025
Dietary Fibre (g)	13.6	3.5	**44.2**
Iron (mg)	4.4 ± 0.2	4.66 ± 0.20	4.86 ± 0.30
Calcium (mg)	11.6 ± 0.1	10.14 ±0.02	11.3 ± 0.1
Phosphorus (mg)	120± 10	65.53± 1.36	**121.1± 8.40**
Vitamin C (mg)	22.4 ± 1.62	20.8 ± 0.1	22 ± 0.5
Mean SD	**33.72±40.29**	**29.22±34.16**	**39.32±42.96**
Std.Error	**12.1**	**10.3**	**12.9**

Table II. SDWP-Sun-dried whole pulp, CDWP- Cabinet -dried whole pulp, FDWP-Freeze -dried whole pulp

Each sample was analyzed in triplicate for both proximate composition and nutrient content. As depicted in Table 2, Freeze-dried tamarillo has the highest moisture content (86.36%) followed by cabinet dried (84.63%) and sun dried (71.73%). This indicated that freeze-drying is the least effective method for moisture removal, while sun drying removes high moisture content. Sun dried tamarillo has the highest ash content (88.33g/100g) compared to cabinet dried (85g/100g) and freeze-dried (11.54g/100g). Ash content refers to mineral content in the sample. Sun drying appears to retain more minerals than the other drying methods. Freeze-dried tamarillo has the highest carbohydrate content (7.76g/100g) followed by cabinet (6.63g/100g) and sun dried (6.5g/100g). Freeze-drying appears to preserve carbohydrates slightly better than other drying methods. Freeze-dried tamarillo has the highest protein content (1.30g/100g) followed by sun dried (1.1g/100g) and cabinet dried (0.74g/100g). Freeze-drying appears to be the most effective method for retaining protein content. The fat content is similar across all three drying methods (around 0.4g/100g). The dietary fiber content of 44.2g / 100g in FDWP, potentially aiding in maintaining a healthy digestive tract and reducing the risk of coronary heart disease (CHD) and certain types of cancer. Additionally, the analysis revealed that the freeze-dried whole fruit of the tamarillo contains higher levels of iron, essential for red blood cell formation and overall growth and development**.** Freeze-drying appears to be most effective for retaining phosphorus. Freeze-dried tamarillo has the highest vitamin C content (22mg/100g) followed by sun dried (22.4mg/100g) and cabinet dried (20.8mg/100g). Vitamin C content is fairly similar across all drying methods. Ascorbic acid (vitamin C), a vital nutrient primarily obtained from fruits and vegetables, serves a dual purpose: disease prevention (e.g., scurvy) and biological antioxidant activity. However, food processing poses a significant challenge to vitamin C stability. Several factors, including pH, temperature, light exposure, residual endogenous enzymes, oxygen availability, and the presence of transition metal ion catalysts, can significantly accelerate vitamin C degradation. Consequently, researchers investigating food processing methods, particularly drying, often employ vitamin C content as a reliable quality indicator. (Senem *et al*., 2016).

3.3. Proximate and nutrient content of Sun dried, Cabinet dried and Freeze-dried flesh of Tamarillo fruit

Nutrients(100g)	**SDF**	**CDF**	**FDF**
Ash (g)	78.33± 10.40	75± 5	90.43±0.75
Moisture (%)	77.16 ± 4.15	80.03 ± 0.15	85 ± 3.2
Energy(kcal)	**33.5**	**32**	**30.7**
Carbohydrate (g)	5.53 ± 0.30	5.4 ± 0.15	6.93 ± 0.25
Protein (g)	1.23 ± 0.30	0.89 ± 0.09	1.63 ± 0.15
Fat (g)	0.38 ± 0.26	0.38 ± 0.005	0.52 ±0.030
Dietary Fibre (g)	12.8	3.8	36.4
Iron (mg)	**4.1 ± 0.1**	**4.1 ± 0.1**	**4.36 ± 0.37**
Calcium (mg)	9.4 ± 0.2	8 ± 0.1	10.26 ±0.20
Phosphorus (mg)	86.42± 0.36	53.2± 0.17	68.33± 2.88
Vitamin C (mg)	**20.4 ± 0.40**	**19.7 ± 0.25**	**20 ± 1.0**
Mean SD	**29.75**±33.8	**25.66**±30.21	**32.05**±33.79
Std.Error	**10.2**	**9.1**	**10.1**

Table III. SDF- Sun-dried flesh; CDF- Cabinet-dried flesh; FDF – Freeze-dried flesh.

Table 3 revealed that the moisture content shows a significant increase, reaching 90% in freeze dried flesh. This indicated that freeze-drying is the least effective method for moisture removal, while sun drying removed more moisture content. Fibers comprising non-starch polysaccharides and totaling 36.4g per 100g of sample in freeze dried samples play a crucial role in lipid and carbohydrate metabolism, reducing blood cholesterol, promoting proper gut function, and aiding in the alleviation of constipation issues (Sarkar *et al.*, 2022). Sun dried tamarillo has the highest ash content (88.33g/100g) compared to cabinet dried (85g/100g) and freeze-dried. Ash content referred to mineral content in the sample. Sun drying retained more minerals than the other drying methods. Tamarillo samples dried in sun exhibited Vitamin C contents of 20.4mg, this is being highly sensitive to heat, undergoes reduction based on the time and temperature during the drying process. Control samples experienced a sharp decline in ascorbic acid content, while blanched samples showed a lesser reduction during drying.

3.4. Proximate and nutrient content of Sun dried, Cabinet dried and Freeze-dried peel of Tamarillo fruit

Nutrients(100g)	**SDP**	**CDP**	**FDP**
Ash (g)	83.33± 5.77	80± 10	81.83±3.17
Moisture (%)	78.93 ± 0.75	79.4 ± 0.2	79 ± 1.0
Energy(kcal)	**26.9**	**27.6**	**23.8**
Carbohydrate (g)	3.53 ± 0.30	4.66 ± 0.25	4.8 ± 0.1
Protein (g)	0.17 ± 0.04	0.33 ±0.15	0.33 ± 0.15
Fat (g)	0.15 ±0.05	0.12 ± 0.025	0.31 ±0.02
Dietary Fibre (g)	**14.2**	5.2	38.3
Iron (mg)	**2.36 ± 0.20**	**3.16 ±0.15**	**3.4 ± 0.26**
Calcium (mg)	9.88 ± 0.07	8.76 ±0.51	10.6 ± 0.1
Phosphorus (mg)	143.53± 3.32	85± 5	114.43± 3.15
Vitamin C (mg)	**21.5 ± 0.47**	**20.4 ±0.45**	**22 ± 1.0**
Mean SD	**34.64**±46.52	**28.50**±34.93	**34.22**±39.39
Std.Error	**14.02**	**10.53**	**11.87**

Table IV. SDP- Sun-dried peel; CDP- Cabinet dried peel; FDP- Freeze-dried peel

As a result of dried peel samples given in Table 4, the dietary fibre content amounts to 38.3 g per 100g of the sample in FDP. The vitamin C content varies, with values of 22g, 21.5g and 20g found in FDP, SDP, CDP respectively. Based on the table, SDP has the highest nutrient content overall, followed by FDP and then CDP. SDP has a higher amount of ash (83.33 g) and calcium (9.88 g) compared to CDP and FDP. The consumption of foods rich in vitamin C aids the body in building resistance against infectious agents and scavenging harmful oxygen-free radicals. Nevertheless, owing to their limited shelf life and seasonal availability, these fruits are typically consumed in processed forms like tamarillo pickle, jam, and other processed varieties (Janicka *et al.*, 2021). Overall, the results revealed that SDP is a more nutrient-rich food than CDP and FDP. However, more research is needed to determine the exact nutrient composition of these products and how it varies between different samples.

Sun drying appears to be the most effective method for preserving most nutrients in tamarillo peel, with the exception of dietary fiber which is highest in freeze-dried peel. However, sun drying also results in the lowest moisture content. It highlighted tamarillo peels as a potential source of natural antioxidants with various applications in food and pharmaceutical industries. It also emphasized the possibility of utilizing a byproduct to create valuable functional ingredients. While it is a seasonal, dried and processed versions offer year-round access. Freeze-drying emerged as the most effective method for preserving nutrients in whole pulp and flesh of tamarillo fruit, as compared to sun drying and cabinet drying. Hence freeze-drying is the most suitable method for preserving the overall nutritional value and bioactive compounds of tamarillo fruit flesh and pulp. Sun drying might be preferable for preserving minerals in tamarillo peels, although it reduced moisture content the most. Steaming appears to be effective in retaining phenolics and flavonoids but may not be a practical preservation method (Dillwyn *et al*., 2021). Steamed fruit and the freeze-dried fruit retained high levels of phenolics and flavonoids, and a nutritional analysis showed that tamarillo is a rich source of nutrients, providing all that the body needs. This fruit is rich in phenols and flavonoids, which are antioxidants that may aid in managing diabetes, heart diseases and cancer.

3.5.Proximate and nutrient content of Freeze-dried Salsa and juice

Nutrients (100g)	**FDS**	**FDJ**
Ash (%)	95.933±0.90	77.66±6.80
Moisture (%)	82.5 ± 1.80	86.33 ± 2.20
Energy(kcal)	**65**	**27**
Carbohydrate (g)	8.5 ± 0.47	6.6 ± 0.6
Protein (g)	1.3 ± 0.08	1.1 ± 0.1
Fat (g)	0.62 ±0.02	0.21 ±0.01
Dietary fibre (g)	34.1	40.2
Iron (mg)	**5.26 ± 0.30**	**2.3 ± 0.35**
Calcium (mg)	12.1 ± 0.15	6.6 ± 0.05
Phosphorus (mg)	144.2± 3.664	45.53± 1.36
Vitamin C (mg)	**21.5 ± 0.2**	**18.6 ± 1.52**
Mean+SD	**49.5+21.8**	**33.6+9.3**
Std.Error	**15.4**	**6.6**

Table V. FDS- Freeze-dried Salsa; FDJ- Freeze dried juice

Table 5 exhibits the nutrient content of freeze-dried salsa and freeze-dried juice since freeze drying was better and retains the maximum nutrients salsa and juice were prepared and freeze dried. The prepared salsa had more iron content than juice. As stated in (Juana *et al.*,

2021) Study showed promise for Tamarillo juice in boosting iron absorption**.** Researchers at the Centre for Food Agriculture, Indonesia have found that Tamarillo (*Solanum betacum* Cav.) is a fruit rich in vitamin C and iron. Their study suggests that consuming Tamarillo juice may increase iron absorption in pregnant women. Iron is an essential mineral for the production of haemoglobin, a protein in red blood cells that carries oxygen throughout the body. Tamarillo is certainly a nutritious fruit with potential health benefits.

3.6. Determination of phenols, flavonoids and glycosides

S.No	Sample	Phenols (mg/100ml)	Flavanoids (mg/100ml)	Glycosides (mg/100ml)
1	**FDWP**	56.4	45.8	16.2
2	**FDF**	31.2	24.0	9.8
3	**FDS**	37.8	28.6	12.4
4	**FDJ**	29.5	19.7	10.2
5	**F**	95	28	10.6
6	**S**	88.5	47.3	14.5
Std.Error		**11.86**	**4.71**	**1.05**
Mean SD		**56.4+29**	**32.2+11.5**	**12.2+2.5**
F=11.774				
P=0.002				

Table VI. FDWP- Freeze-dried Whole Fruit; FDF - Freeze-dried Flesh; FDS- Freeze-dried Salsa; FDJ- Freeze-dried Juice; F- Fresh fruit; S- Steamed fruit.

To understand how drying methods affect nutrient content, researchers analyzed freeze-dried samples for phenolics, flavonoids, and glycosides. Table 6, compared the amounts of these phytochemicals in freeze-dried samples, fresh tamarillo, and steamed tamarillo. Steamed and freeze-dried fruits showed the highest phenolic content (88.5 mg GAE/100 g and 56.4 mg GAE/100 g, respectively). Similarly, steamed and freeze-dried fruits had the most flavonoids (47.3 mg/100ml and 45.8 mg/100ml, respectively). Flavonoids are natural antioxidants that may help prevent diseases. According to (Saeed *et al*., 2019) presence of phenolics and flavonoids in fruits and vegetables likely contributed to their antioxidant potency, which is crucial in fighting diseases caused by oxidative stress. Notably, steamed fruit contained the most glycosides (16.2 mg/100ml), followed by freeze-dried fruit (14.5 mg/100ml) and salsa (12.4 mg/100ml). Overall, the table suggested that Samples F and S have the highest concentrations of phenols, flavonoids, and glycosides. Interestingly, the study also found cardiac glycosides in freeze-dried fruit, which may have antitumor properties.

Table VII. Statistical results

Tukey Test: Statistical difference between sun, cabinet and freeze-dried whole pulp of tamarillo fruit			
Comparison	**Q**	**P**	**P<0.050**
FDWP vs SDWP	3.467	0.038	Yes
FDWP vs CDWP	3.317	0.050	Yes
CDWP vs SDWP	0.151	0.994	No
Chi-square= 7.860 with 2 degrees of freedom. (P = 0.020)			
Tukey Test: Statistical difference between sun, cabinet and freeze-dried flesh of tamarillo fruit			
FDF vs CDF	4.523	0.004	Yes
FDF vs SDF	2.261	0.246	No
SDF vs CDF	2.261	0.246	No
Chi-square= 10.714 with 2 degrees of freedom. (P = 0.005)			
Tukey Test: Statistical difference between sun dried, cabinet dried and freeze-dried flesh of tamarillo fruit			
FDP vs SDP vs CDP	No		
Chi-square= 5.333 with 2 degrees of freedom. (P = 0.069)			

The statistical analysis data showed in Table 7, revealed that there is a statistically significant difference between the drying methods for tamarillo fruit. Tukey test under RMANOVA was used to determine which drying methods were statistically different from each other. Freeze-dried vs Sun-dried vs Cabinet dried: The freeze-dried flesh (FDF) was statistically different from both the sun-dried (SDWP) and cabinet-dried (CDWP) flesh (p-values < 0.05). There was no statistically significant difference between the sun-dried and cabinet-dried flesh (p-value = 0.994). Chi-Square: The Chi-square test statistic (7.860) with 2 degrees of freedom yielded a p-value of 0.020, which is statistically significant. This indicated that the observed differences in nutrient content between the drying methods are likely due to more than just random variation.

Conclusion

Among drying techniques, freeze-drying emerged as the most effective method for preserving the overall nutritional profile of *Solanum betaceum* (tamarillo) fruit, particularly its bioactive compounds and dietary fibre content. Sun drying offers the advantage of maximizing mineral content, especially in the peels, and it also leads to the most significant moisture loss. Steaming, on the other hand, demonstrated superior retention of phenolic and flavonoid content (antioxidants) but may not be suitable for large-scale commercial preservation due to practicality limitations. Further investigation into alternative drying methods, such as microwave or vacuum drying, is warranted to evaluate their potential advantages in terms of both nutrient retention and processing efficiency. Additionally, research should be directed towards developing practical and cost-effective procedures for large-scale steaming or freeze-drying of tamarillos to facilitate their commercial application.

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Conflict of Interest

All authors declared that they have no conflict of interest.

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