

Studies on Effects of Drying Methods on Quality Characteristics of Tomato Pulp Leather

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Abstract. The present study investigated the drying characteristics and quality attributes of tomato pulp leather prepared using tray drying and hot air oven methods at temperatures of 60°C, 65°C, and 70°C. Sensory evaluation identified the best samples as T3 (hot air oven at 70°C for 6-5 hours) and T5 (tray dryer at 65°C for 8-9 hours), which exhibited superior drying and sensory characteristics according to a 9-point hedonic scale. Physicochemical analysis revealed that the moisture content, ash content, pH, total soluble solids (TSS), total sugars, and vitamin C content decreased gradually during the 45-day storage period for both T3 and T5 samples. The initial moisture content of the prepared tomato pulp leather was 18.5% and 18.6% for T3 and T5, respectively, which decreased to 17.9% for both samples by the 45th day of storage. The ash content, pH, TSS, total sugars, and vitamin C content also showed a decreasing trend during storage. The drying kinetics of the T3 sample showed a maximum drying rate of 0.33 g/min in the first hour, which decreased to g/min in the last hour, reaching an equilibrium moisture content of 18.5% after 7 hours of drying. The decrease in drying rate was consistent with the lower rate of moisture diffusion inside the tomato pulp leather compared to the rate of moisture evaporation from the surface. In conclusion, tray drying at 70°C for 7 hours proved to be the most effective method for producing high-quality tomato pulp leather, ensuring optimal drying rate, superior retention of nutrients, and good sensory attributes, making it suitable for commercial production of tomato-based snack products. Microbiological analysis revealed that yeast and mold counts increased gradually during the 45-day storage period. However, the microbial load remained within acceptable limits, ensuring the microbiological safety of the tomato pulp leather throughout storage.

Keywords: Tomato Pulp Leather, Hot Air Oven, Tray Dryer, Drying Characteristics

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) which is a climacteric fruit is widely cultivated and consumed across the globe and is valued for its rich nutritional profile, especially its high content of vitamins, minerals, and antioxidants such as lycopene and vitamin C [1]. Tomatoes are perishable fruits that deteriorate rapidly during the post-harvest handling which necessitates the need for various processing techniques to extend their shelf life and maintain quality during storage [2]. To reduce these losses and increase product shelf life, the development of dehydrated tomato-based food products has gained massive attention in recent years [3].

One of such products is fruit pulp leather a thin, flexible sheet developed by drying fruit pulp under controlled drying conditions. Fruit leather is a concentrated fruit product that preserves the natural color, flavor, and nutritional properties of the original fruit, while also providing advantages such as longer shelf life, easy packaging, and consumer convenience [4]. Its portability, minimal processing, and lack of synthetic additives make it an appealing option as a healthy snack. Tomato leather prepared from fresh tomato pulp proposes a novel approach to utilizing excess tomato production, providing the nutritional benefits of tomatoes and a shelf-stable and consumer friendly form [5]. The method and conditions of drying significantly influence the quality attributes of the resulting fruit leather. Traditional drying methods like sun drying are cost-effective but can lead to uneven moisture removal, increased risk of microbial contamination, and

degradation of heat-sensitive nutrients [6]. In a study, open sun drying led to significant losses of vitamin C and β -carotene in dried mango slices, attributing these losses to prolonged exposure to sunlight and oxygen during the drying process [7]. On the contrary, controlled drying techniques, such as tray drying and hot air oven drying, offer more uniform and hygienic processing conditions, which can better preserve the nutritional and sensory characteristics of the finished product [8-9].

In this study, the drying characteristics and quality attributes of tomato pulp leather were assessed under varying temperature conditions using tray drying and hot air oven techniques. The analysis included key physicochemical parameters such as moisture content, ash content, pH, total sugars, reducing sugars, total soluble solids, and vitamin C concentration.

2. MATERIAL AND METHODS:

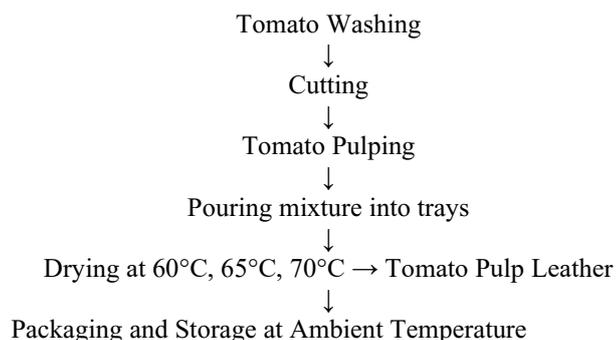
This section describes the materials and methods used to carry out the experimental work for the study titled "Studies on the Effects of Drying Methods on the Quality Characteristics of Tomato Pulp Leather."

2.1 Raw Materials:

The materials used for the preparation of tomato pulp leather included fresh tomatoes, sugar, corn flour, and citric acid. Low-Density Polyethylene (LDPE) bags were utilized as packaging material. All ingredients and

Procedure

The procedure of prepared in Tomato Pulp Leather was followed as per process.



packaging materials were procured from the local market in Mahewa, Prayagraj district, Uttar Pradesh.

2.2 Sample Formulation

Tomato pulp leather was made with the following ingredients: tomato pulp (72.7%), sugar (23%), corn flour (4%), and citric acid (0.30%). Six different samples were prepared and divided into two groups based on the drying method. Samples T₁, T₂, and T₃ were dried using a tray dryer at 60°C, 65°C, and 70°C, respectively. The other samples, T₄, T₅, and T₆, were dried using a hot air oven at the same temperatures. The samples were collected and tested at regular intervals to check how the drying temperature and method affected the quality of the tomato pulp leather. Each test was repeated three times and the data collected comprised of physical, chemical and sensory tests which includes tests like moisture content, texture, color, total sugars, acidity, and overall taste. Standard procedures were utilized for physicochemical analysis and the results were reevaluated statistically through statistical analysis. The tomato pulp leather samples were packed in low-density polyethylene (LDPE) pouches and kept at ambient temperature (28±2°C) after drying. Over a 45-day period, storage experiments were performed to observe changes in physicochemical characteristics, sensory qualities and microbiological quality at 0, 15, 30, and 45 days.

3. Analytical Methods

The physicochemical properties of the developed tomato pulp leather were evaluated using standard analytical procedures. Moisture content was determined following the method outlined by the Association of Official Analytical [10].



Figure 1. Tomato pulp leather prepared by hot Air Oven drying



Figure 2. *Tomato pulp leather prepared by different drying methods.*

The experimental data obtained from the six treatment combinations were statistically analyzed by means of a Completely Randomized Design (CRD) to verify the significance of the influences of drying methods and temperatures on the quality attributes of tomato pulp leather. Each treatment replicated three times for more reliable results and minimum experimental error. The mean values and standard deviations were also evaluated and Analysis of Variance (ANOVA) was done to evaluate the differences among treatments. Where significant differences were obtained ($p < 0.05$), Duncan's Multiple Range Test (DMRT) was utilized for mean separation to detect statistically significant effects of the treatments. Complete statistical analysis was calculated using SPSS and Microsoft Excel.

3.1 Microbiological Analysis

Microbiological quality of the tomato pulp leather samples was assessed by determining the yeast and mold count during storage. A 10 g sample of tomato pulp leather was homogenized with 90 mL of sterile peptone water to prepare a dilution. Serial dilutions were made and plated on Potato Dextrose Agar (PDA) supplemented with 0.01% chloramphenicol to inhibit bacterial growth. Plates were incubated at $28 \pm 2^\circ\text{C}$ for 3–5 days, and colony-forming units (cfu) were counted and expressed as cfu/mL.

3.2 Sensory Evaluation

A 9-point hedonic scale was used to sensory evaluate the tomato pulp leather samples; 1 signaled "dislike extremely" and 9 signaled "like extremely." Ten-member semi-trained panel was chosen to assess the samples on color, taste, flavor, texture, appearance, and general acceptability. Under controlled circumstances, a sensory evaluation lab carried out the assessments. Panelists were given coded samples shown in a random order and instructed to rinse their mouths with water between assessments.

4. Results and Discussion

The study aimed to estimate the impact of various drying methods on the physico-chemical and sensory attributes of tomato pulp leather giving understandings into standardizing processing conditions for higher product quality.

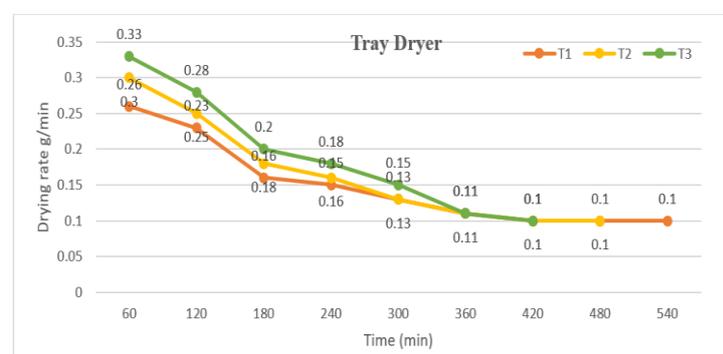
4.1 Drying Rate

Figure 3 and Figure 4 depicts the differences in moisture content and drying rate of tomato pulp leather during the drying process. The sample dried at 70°C using a tray dryer (T3) had the highest drying rate across the treatments. In the first drying phase (up to about 7 hours), a fast decrease in moisture content was noted, succeeded by a steadier drop as the product neared its equilibrium moisture level of 18.5%.

The drying rate fluctuated from 0.33 g/min in the initial hour to 0.1 g/min in the concluding stages of drying. No identifiable constant-rate phase was detected; rather, the drying transpired solely during the falling-rate phase. This phenomenon is typically observed in materials with elevated initial moisture content, where the drying rate is predominantly influenced by the internal diffusion of moisture rather than surface evaporation. During the initial phases, the surface remains saturated, facilitating a comparatively elevated rate of moisture extraction. As drying advances, the decrease in internal moisture availability constrains the drying rate [11].

These findings align with previous investigations by [12] and [13], which documented a comparable trend in the drying behaviour of high-moisture food items. Figure 1 illustrates that the drying rate diminishes more swiftly during the initial high-moisture phase, then declining gradually when the material attains lower moisture levels.

Figure 3. *Effect of Hot Air Oven Drying on Drying Rate of Tomato Pulp Leather*



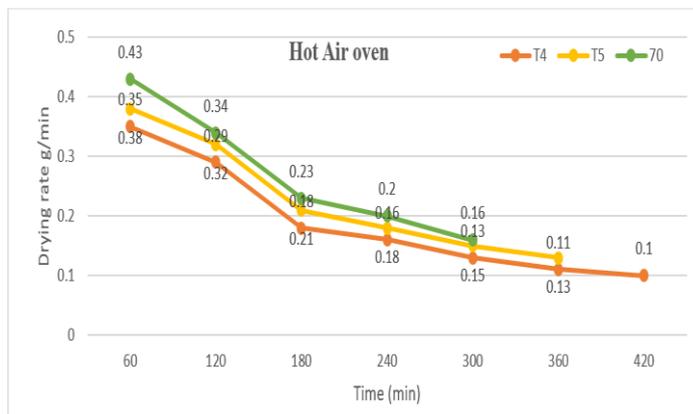


Figure 4. Effect of Hot Air Oven Drying on Drying Rate of tomato Pulp Leather

4.1.2 Rehydration Ratio

Figure 5 illustrates the rehydration behaviour of the tomato pulp leather samples. Of all treatments, the sample dried at 70°C in the tray dryer (T3) demonstrated the highest rehydration ratio, with a measured value of 1.83. This enhanced performance is due to the efficient drying properties of this treatment, which likely maintained the product's structural integrity more effectively than alternative techniques [14].

The rehydration ratio serves as an important indicator of the quality of dehydrated products. A higher rehydration

ratio implies that the dried matrix retained a porous structure, thereby facilitating the absorption of water and restoring the original texture upon rehydration. This suggests minimal cellular damage during the drying process, enabling efficient water uptake [15].

Furthermore, the rehydration ratio can reflect the extent of physical and chemical changes the product has undergone during dehydration. The results obtained in this study are in close agreement with the findings reported [16], who also observed that drying conditions significantly influence the rehydration capacity of fruit leathers and similar food matrices.

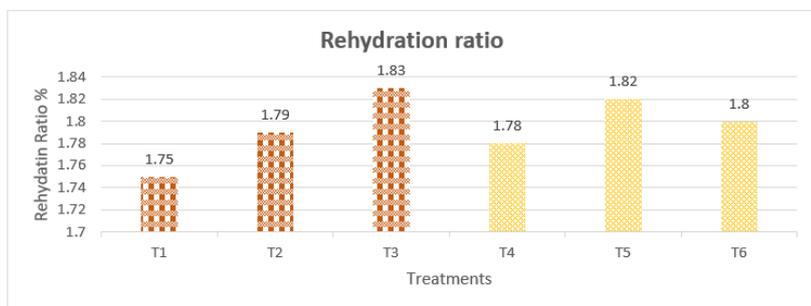


Figure 5. Rehydration ratio of Tomato pulp leather dehydrated at different temperatures.

4.2 Physico-chemical Properties

Table 1 gives the results of the physico-chemical investigation of tomato pulp leather processed using tray dryers (T1, T2, T3) and hot air ovens (T4, T5, T6). Among all the treatments, sample T3 (tray dryer at 70°C) demonstrated the most satisfactory physico-chemical

characteristics formulating it the most appropriate treatment based on quality parameters.

4.2.1 Moisture Content

The moisture content of tomato pulp leather of treatment T3 which was dried at 70°C in a tray dryer, was documented at 18.5%. This value was within the suggested

moisture content ranging from 15–25% for fruit leather products, as specified by confirming together product stability as well as compliance with food safety standards. The successful elimination of water during drying is mainly due to the heightened vapor pressure differential at higher temperatures, which facilitates moisture movement from the interior structure to the surface, resulting in efficient evaporation.

The reduction of moisture is essential for prolonging the shelf life of dehydrated items, since it inhibits microbial proliferation and enzymatic processes. Numerous studies have shown that reduced moisture content in fruit leathers enhances textural integrity and diminishes spoiling risk during storage [17]. The homogeneous drying attained with tray dryers also inhibits localized over-drying or under-drying, which may jeopardize product quality. Comparable moisture content levels have been documented in other fruit-based leathers, including papaya, mango, and guava, when exposed to regulated convective drying techniques. The observed value in T3 indicates an efficiently tuned drying procedure appropriate for commercial use.

4.2.2 Ash Content

Treatment T3 had the greatest ash concentration at 1.62%, signifying a comparatively greater retention of mineral components post-drying. Ash content serves as an indirect measure of total mineral content, and its retention in dried fruit products is essential for preserving nutritional quality, especially in value-added snack meals aimed at health-conscious consumers.

Despite T3 producing the greatest ash value, a general decline in ash content was observed with rising drying temperatures across treatments. This inverse association is probably attributable to the partial volatilization of mineral-bound organic molecules or interactions with acidic components that may render minerals unstable or undetected [7].

Notwithstanding this possible loss, the retention of 1.62% ash percentage in T3 indicates that tray drying at 70°C maintains a significant portion of the original mineral composition. These results align with findings from prior studies on tomato-based leathers and dried fruit products, underscoring the significance of selecting suitable drying settings to optimize moisture removal and nutrient preservation.

4.2.3 pH

The pH value for treatment T3 was observed at 4.40, signifying mild acidity. A gradual yet persistent decrease in pH was noted with increasing drying temperatures across all treatments. The increase in acidity is likely due to a heightened concentration of organic acids, such as

citric and malic acids, during the drying process as water content diminishes and solutes become more concentrated. Additionally, heat-induced breakdown of buffering chemicals within the pulp matrix may also contribute to this decrease in pH [16].

Reduced pH levels in dried fruit products fulfil two purposes: they improve microbiological stability by establishing an unfavourable environment for spoiling organisms and favourably influence the distinctive acidic flavor in tomato-based snacks indicate that pH fluctuations are frequently noted during the thermal processing of fruit and vegetable leathers and are typically regarded as advantageous for safety reasons.

An extreme decrease in pH may signify excessive acidification or degradation processes that could impact sensory quality. A pH of 4.40 in T3 signifies an ideal equilibrium, preserving both flavor and safety, consistent with analogous findings in earlier research on mango and mixed fruit leathers.

4.2.4 Total Soluble Solids (TSS)

The treatment with the greatest total soluble solids (TSS) concentration was sample T3, which was dried in a tray drier at 70°C, yielding a measured value of 78.40°Brix. The increase in TSS corresponds with the reduction in moisture content during drying, as water is removed and soluble solids—primarily sugars—become more concentrated. This concentration effect enhances the sweetness and overall solid content of the meal, favorably affecting texture, shelf life, and flavor. Multiple studies have recorded the rise in TSS values with increased drying temperatures, underscoring the importance of dehydration in concentrating both sugar and non-sugar components in fruit-based products. The study revealed that total phenolic content, flavonoids, and β -carotene rose with higher drying temperatures, reaching a maximum at 90°C.

4.2.5 Total Sugar

The maximum total sugar content was also observed in sample T3, with a value of 13.63 g/100 g. The high total sugar concentration may be attributed to the reduction in water activity and the breakdown of complex carbohydrates into simpler sugars during thermal processing. However, it is important to note that some losses in sugar content could occur due to acid hydrolysis during heating, which leads to partial conversion of disaccharides and polysaccharides into monosaccharides. Despite this, the concentration effect from moisture loss results in an overall increase in measurable total sugars.

4.2.6 Reducing Sugars

Sample T3 had a decreasing sugar content of 8.40 g/100 g, the highest of all treatments. The elevation in reducing sugar concentration with temperature is due to the hydrolysis of polysaccharides into simpler reducing sugars like glucose and fructose. Elevated temperatures expedite this process, increasing the concentration of reducing sugars, which significantly contribute to browning events during drying (e.g., Maillard reactions). This impacts both the nutritional composition and the color and flavor of the final product.

4.2.7 Vitamin C

Sample T3 demonstrated the highest content of vitamin C, measured at 16.13 mg/100 g. Although higher than alternative treatments, this value was still significantly lower than the standard reported in fresh tomatoes. Vitamin C is a thermolabile vitamin, and its degradation during drying predominantly occurs due to oxidative and thermal mechanisms. Even at modest drying temperatures, certain nutrient losses are inevitable, especially with prolonged exposure. The limited retention seen in the T3 sample suggests that the drying conditions in this treatment may have attained an optimal balance between moisture removal and nutrient preservation.

Table 1: Effect of Tray dryer and Hot Air oven drying method on physico-chemical characteristics of tomato pulp leather

Parameters	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆
Moisture content (%)	18.9	18.7	18.5	18.8	18.6	18
Ash content (%)	1.58	1.54	1.62	1.56	1.60	1.53
pH	4.47	4.45	4.40	4.45	4.39	4.43
TSS (°Brix)	78.25	78.33	78.4	78.3	78.42	78.28
Total sugar (g/100g)	13.42	13.55	13.63	13.55	13.58	13.49
Reducing Sugars (g/100g)	8.47	8.45	8.4	8.49	8.41	8.46
Vitamin. C (mg/100g)	15.67	15.54	16.13	15.72	16.09	15.69

4.3 Storage Studies

Storage studies were undertaken over a 45-day period at ambient temperature to assess the shelf stability of the prepared tomato pulp leather at ambient temperature (28±2°C) temperature. Samples were enclosed in low-density polyethylene (LDPE) pouches and examined at

intervals of 0, 15, 30, and 45 days. Table 2 presents the fluctuations in physicochemical parameters, including moisture content, ash content, and pH, throughout storage.

4.3.1 Moisture Content

On Day 0 of the storage period, the moisture level of the tomato pulp leather from treatment T3 (tray dryer at 70°C) was documented at 18.5%. A progressive decrease in moisture content was noted over the storage duration, diminishing to 18.2% on Day 15, 17.9% on Day 30, and ultimately to 17.8% on Day 45. The noted reduction in moisture content may be ascribed to the porosity of LDPE

packaging, facilitating gradual moisture movement into the external environment. Such losses may also be affected by environmental storage conditions, including temperature and relative humidity.

4.3.2 Ash Content

The initial ash content in the T3 treatment was determined to be 1.62%. A gradual decrease was seen during storage, with values falling to 1.59% on Day 15, 1.56% on Day 30, and 1.51% on Day 45. The reduction in ash content during storage may result from the sublimation or volatilization of specific mineral salts or the interaction of minerals with air gases, potentially causing their conversion into undetected forms during analysis. The decline may also indicate slight chemical alterations within the leather matrix due to extended exposure to environmental conditions.

4.3.3 pH

The initial pH of the tomato pulp leather (T3) was measured at 4.40 on Day 0. During the 45-day storage duration, the pH progressively declined, attaining 4.37 on Day 15, 4.33 on Day 30, and 4.29 on Day 45. The noted decrease in pH may be ascribed to the continuous biochemical reactions involving residual enzymatic or microbiological activity, resulting in the production of organic acids. While LDPE packaging restricts microbial penetration, the formation of natural acidity may nevertheless transpire due to internal oxidation or the degradation of complex chemicals.

4.3.4 Total Soluble Solids (TSS)

On Day 0, the total soluble solids (TSS) concentration in tomato pulp leather from treatment T3 (tray dryer at 70°C) was measured at 78.40°Brix. A little although continuous rise in TSS was noted during the storage duration, reaching 78.42°Brix on Day 15, 78.44°Brix on Day 30, and 78.45°Brix on Day 45. The slow increase is due to the

progressive decrease in moisture content, resulting in the concentration of soluble substances like sugars, organic acids, and other solutes. Moisture leakage is possible even through LDPE packaging, leading to the concentration effect.

4.3.5 Total Sugars

The total sugar level of sample T3 was tested at 13.63 g/100 g on Day 0. A progressive reduction in total sugar level was observed during the storage period: 13.59 g/100 g on Day 15, 13.55 g/100 g on Day 30, and 13.49 g/100 g on Day 45. This drop may be ascribed to acid hydrolysis, which transforms disaccharides and polysaccharides into monosaccharides, along with potential sugar degradation during storage. Additional contributing elements encompass non-enzymatic browning and Maillard processes, particularly under ambient temperature circumstances. The findings correspond with those of [17], who documented analogous reductions in total sugars during the preservation of fruit-based products.

4.3.6 Reducing Sugars

Initially, the reducing sugar concentration in T3 was measured at 8.40 g/100 g. A gradual yet consistent rise was noted over time, culminating in 8.43 g/100 g on Day 15, 8.45 g/100 g on Day 30, and 8.49 g/100 g on Day 45. This rise can be attributed to the hydrolysis of complex carbohydrates into reducing sugars, including glucose and fructose. The product's slightly acidic pH may promote hydrolysis during storage. Moreover, the transformation of non-reducing carbohydrates at ambient settings contributes to the noted rise.

4.3.7 Vitamin C Content

4.3.8 Yeast and Mold Count

The microbiological assessment of the tomato pulp leather (T3) indicated that the yeast and mold count was non-existent on Day 0. A steady rise was seen during storage at ambient temperature. On Day 15, the count was 1.41×10^2 cfu/ml, which rose to 2.95×10^2 cfu/ml on Day 30 and 5.59×10^2 cfu/ml on Day 45. The rise in microbial load during storage is due to residual moisture and the porosity of LDPE packaging, which may allow for oxygen and moisture exchange that fosters microbial development. Despite being within acceptable limits for dried fruit goods, the trend underscores the necessity for enhanced packaging to prolong shelf life.

4.4 Sensory Analysis

The sensory evaluation of tomato pulp leather samples was performed on a nine-point hedonic scale to evaluate color, taste, flavor, texture, and appearance (Table 2). Treatment T3 (tray dryer at 70°C) consistently achieved the highest marks across

The Vitamin C concentration in sample T3 was 16.13 mg per 100 g at the onset of the storage period. A progressive reduction in ascorbic acid was observed, with concentrations diminishing to 16.00 mg/100 g on Day 15, 15.80 mg/100 g on Day 30, and 15.61 mg/100 g on Day 45. The deterioration of vitamin C during storage is chiefly because to its susceptibility to environmental influences including oxygen, heat, and light. These variables expedite oxidative processes, transforming ascorbic acid into dehydroascorbic acid and subsequently into furfural or other degradation products. The inadequate barrier qualities of LDPE packaging may let oxygen infiltration, resulting in the degradation of vitamin C.

Table 2 Effect of Tray drying on physico-chemical characteristics of tomato pulp leather during storage study

Day	Moisture content (%)	Ash content (%)	pH	TSS (°Brix)	Total sugar (g/100g)	Reducing Sugars (g/100g)	Vitamin C (mg/10g)
0	18.5	1.62	4.40	78.40	13.63	8.40	16.13
15	18.2	1.59	4.37	78.42	13.59	8.43	16.00
30	17.9	1.56	4.33	78.44	13.55	8.45	15.80
45	17.8	1.51	4.29	78.45	13.49	8.49	15.61

all samples: color (8.00), taste (8.00), flavor (7.50), texture (9.00), appearance (9.00), and overall acceptance (8.00). The ratings indicate enhanced organoleptic quality in sample T3, presumably resulting from better drying conditions that maintained natural color and flavor ingredients. During the storage period, a downward trend in sensory scores was observed across all metrics, likely due to the decomposition of flavor components and minor textural alterations resulting from moisture loss. Nevertheless, treatment T3 maintained superior sensory qualities during storage in comparison to the other treatments.

5. Conclusion

The current research, entitled “Study on Effects of Drying Methods on Quality Characteristics of Tomato Pulp Leather,” sought to assess the influence of various drying techniques specifically, tray drying and hot air oven drying on the quality of tomato pulp leather. Both drying techniques were employed at 70°C. Among the treatments

examined, sample T3 (tray dryer at 70°C) exhibited superior quality attributes. Post-drying study indicated that T3 exhibited advantageous physico-chemical characteristics: moisture content (18.5%), ash content (1.62%), pH (4.40), total soluble solids (78.48°Brix), total sugar (13.42 g/100 g), reducing sugar (8.40 g/100 g), and vitamin C content (16.13 mg/100 g). Storage studies conducted over 45 days at ambient temperature revealed a general decline in moisture content, ash content, total sugars, pH, and vitamin C levels. Conversely, TSS and decreasing sugar concentrations exhibited a marginal rise attributable to moisture evaporation and ongoing

hydrolysis of complex carbohydrates. A progressive rise in microbial burden was noted, but below acceptable limits, whereas sensory qualities experienced a modest reduction with time. In conclusion, tray drying at 70°C (T3) shown the highest efficacy for producing tomato pulp leather with superior nutritional, microbiological, and sensory attributes. The product demonstrated satisfactory shelf stability for 45 days when stored in LDPE pouches under ambient settings.

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