Comparative Effects of Oven and Microwave Drying on Nutrient Retention and Consumer Acceptability of Watermelon (Citrullus Lanatus)

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ABSTRACT

Background: Watermelon (Citrullus lanatus) is a nutrient-rich fruit with a high moisture content (~92%), making it highly perishable and prone to post-harvest losses. Preservation through drying can reduce spoilage; however, the choice of drying method and pre-treatment may impact nutrient retention and sensory quality. Methods: This study assessed the effects of oven drying at 54°C and microwave drying at 60°C on the proximate composition, mineral content (iron, calcium), vitamin retention (vitamin C, β-carotene), total soluble solids (TSS), and sensory attributes of watermelon slices, both untreated and pre-treated with ascorbic acid solution (3 g/250 ml). Analyses followed AOAC-standardized methods, while sensory evaluation was conducted by a 15-member trained panel using a 9-point hedonic scale. Results: Oven drying retained higher vitamin C (24.53 mg/g) and β-carotene (14.56 mg/g) compared to microwave drying (16.78 mg/g and 8.56 mg/g, respectively) ($p < 0.05$). Ascorbic acid pre-treatment improved iron retention (1.62 mg/g in oven-dried slices) but reduced vitamin stability. Sensory scores were highest for untreated oven-dried samples, with appearance (8.33), taste (7.87), and overall acceptability (8.00) outperforming other treatments. Microwave drying reduced processing time but increased TSS (88.47°Brix) and negatively affected sensory attributes. Conclusion: Oven drying without chemical pre-treatment is recommended for optimal nutrient preservation and consumer acceptability in dehydrated watermelon products.

Keywords: Watermelon dehydration; Oven drying; Microwave drying; Ascorbic acid pre-treatment; Nutrient retention; Sensory evaluation

INTRODUCTION

Watermelon (*Citrullus lanatus*) is a widely consumed fruit prized for its high moisture content (about 92%), rich nutritional profile, and bioactive compounds such as lycopene, vitamins A and C, and citrulline [1]. Believed to have originated in West Africa, it plays an important role as a hydrating food in tropical regions and has been associated with therapeutic benefits, including antihypertensive effects [2]. Despite its value, watermelon is highly perishable, with post-harvest losses exceeding 30% in many developing countries [3]. Dehydration provides a viable means of extending shelf life and improving availability, but the choice of drying method greatly influences the preservation of nutrients and sensory quality [4].

Traditional drying approaches, such as sun drying and cabinet tray drying, often result in the degradation of heat-sensitive vitamins due to prolonged exposure to high temperatures [5]. Microwave drying has emerged as an energy-efficient option, capable of reducing drying time by 40–60% compared with conventional oven drying [6]. Conversely, oven drying at moderate temperatures (50–60°C) has been shown to better maintain color and texture in fruits such as apples [7]. For watermelon, research has primarily centered on fresh consumption and seed utilization [8], with limited studies assessing optimized dehydration methods. Pre-treatments, such as dipping in ascorbic acid, may enhance nutrient retention, but their effects on overall quality remain insufficiently explored [9].

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To date, no comprehensive study has compared the effects of oven and microwave drying on watermelon concerning the retention of heat-sensitive vitamins (vitamin C and β-carotene), stability of minerals such as iron and calcium, sensory acceptability, and the influence of ascorbic acid pre-treatment. This gap in knowledge limits the development of efficient, nutrient-preserving drying techniques for large-scale or industrial use [10].

The present study addresses these gaps by evaluating the effects of oven drying at 54°C and microwave drying at 60°C on ascorbic acid-pre-treated (3 g/250 ml) and untreated watermelon slices. Nutrient composition was determined using AOAC-standardized methods [11], while sensory quality was assessed by a 15-member trained panel. Drying kinetics and total soluble solids (TSS) were also measured. The findings from this work guide for optimizing watermelon dehydration methods that balance processing efficiency with the preservation of nutritional and sensory qualities.

MATERIALS AND METHODS

Source of Raw Materials and Sample Preparation

Fresh, mature watermelon fruits (Citrullus lanatus) were purchased from North-Bank Market, Makurdi, Nigeria. Fruits were washed thoroughly to remove surface contaminants, peeled, and sliced uniformly into 10-mm cubes using stainless steel knives. Slices were divided into two groups: Pre-treated: Dipped in 250 ml distilled water containing 3 g ascorbic acid for 10 min [12]; Control: No chemical treatment. Excess moisture was blotted with absorbent paper before drying.

Drying Methods

Oven Drying

Samples were spread in a single layer on stainless steel trays and dried in a forced-air oven (Model TT-9053, Techmel USA) at 54°C for 24 hr [13]. The oven door was slightly ajar to facilitate moisture escape. Drying was terminated when slices attained a leathery texture with no visible moisture.

Microwave Drying

Samples were placed on microwave-safe trays and dried in a domestic microwave (800 W) at 60°C for 24 hr [13]. Power was set to medium (50%) with rotation every 30 min to ensure uniform heating.

Analytical Methods

Moisture Content and Drying Rate

Moisture content was determined by AOAC 930.15 [11]: Two grams of sample were dried at 105°C in pre-weighed Petri dishes to constant weight;

% Moisture content = $\frac{weight\ loss}{weight\ of\ sample} \times \frac{100}{1}$

Drying rate (R) was derived using Fick's diffusion model [15]:

$$R = -D \cdot \frac{dC}{dx}$$

Total Soluble Solids (TSS)

TSS was measured using a digital refractometer (Atago PAL-1) at 20°C, following AOAC 932.12 [11]. Results were expressed as °Brix.

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Mineral Analysis

Iron (Fe) and calcium (Ca) were quantified by atomic absorption spectroscopy (PerkinElmer AAnalyst 400) [11]: One gram of sample was digested with $HNO_3/HClO_4$ (10:4 v/v). Absorbance was measured at 248.3 nm (Fe) and 422.7 nm (Ca).

Vitamin Analysis

Vitamin C: Determined using HPLC (Shimadzu LC-20A) with UV detection at 245 nm, after extraction in 0.1% metaphosphoric acid [16]. β-Carotene: Determined using HPLC with a C18 column; mobile phase: methanol/acetonitrile (90:10 v/v) [17].

Sensory Evaluation

A 15-member panel (students and staff of the Food Science Department) evaluated appearance, aroma, taste, texture, and overall acceptability using a 9-point hedonic scale (1 = "dislike extremely," 9 = "like extremely") [18]. Samples were randomized, and water was provided for palate cleansing.

Statistical Analysis

Data were analyzed by one-way ANOVA using SPSS v26. Mean separations were performed using Duncan's Multiple Range Test (DMRT) at $p < 0.05$ significance level [19].

RESULTS AND DISCUSSION

Drying Kinetics

Microwave Drying: Untreated samples exhibited rapid moisture loss (1.96% → 0.38% in 30 min). Ascorbic acid pre-treated samples showed delayed drying initially (15–30 min) due to surface barrier formation, followed by accelerated moisture removal after 20 min (Fig. 1).

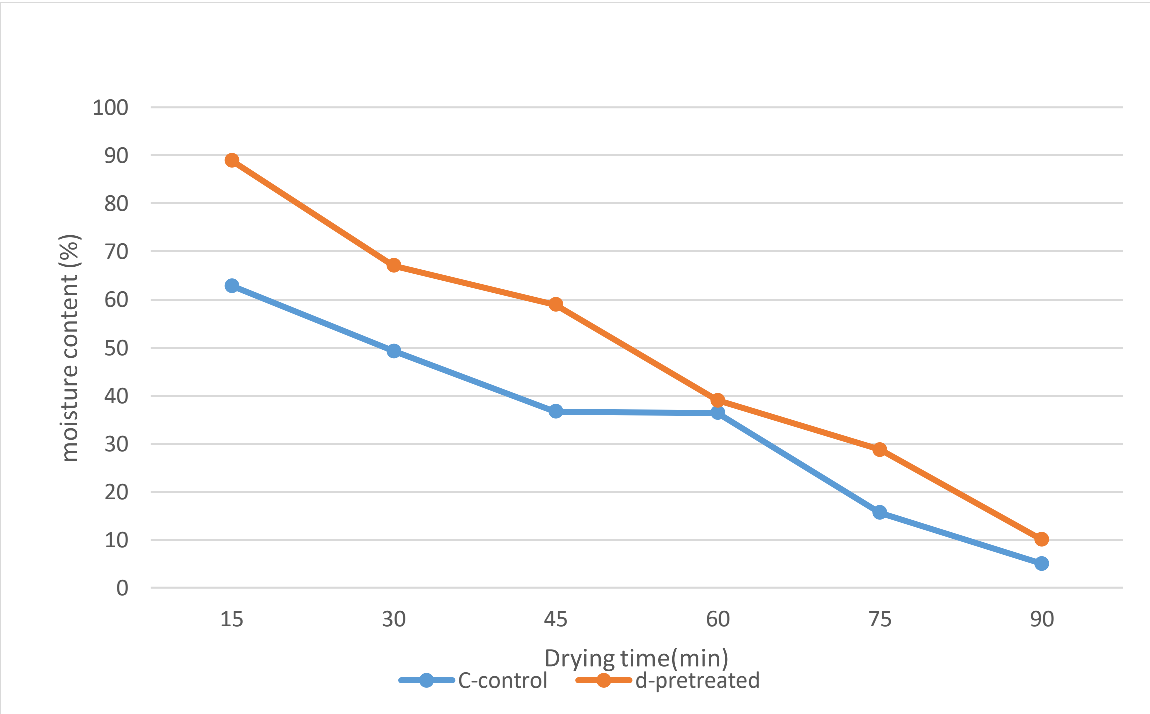

Figure 1: Drying rate of watermelon slices dried in microwave. Key: C = control; D = pre-treated.

Oven Drying: Untreated slices achieved target moisture (<5%) in 9 hr. Pre-treated slices required 12 hr, indicating that ascorbic acid impeded early-stage evaporation (Fig. 2).

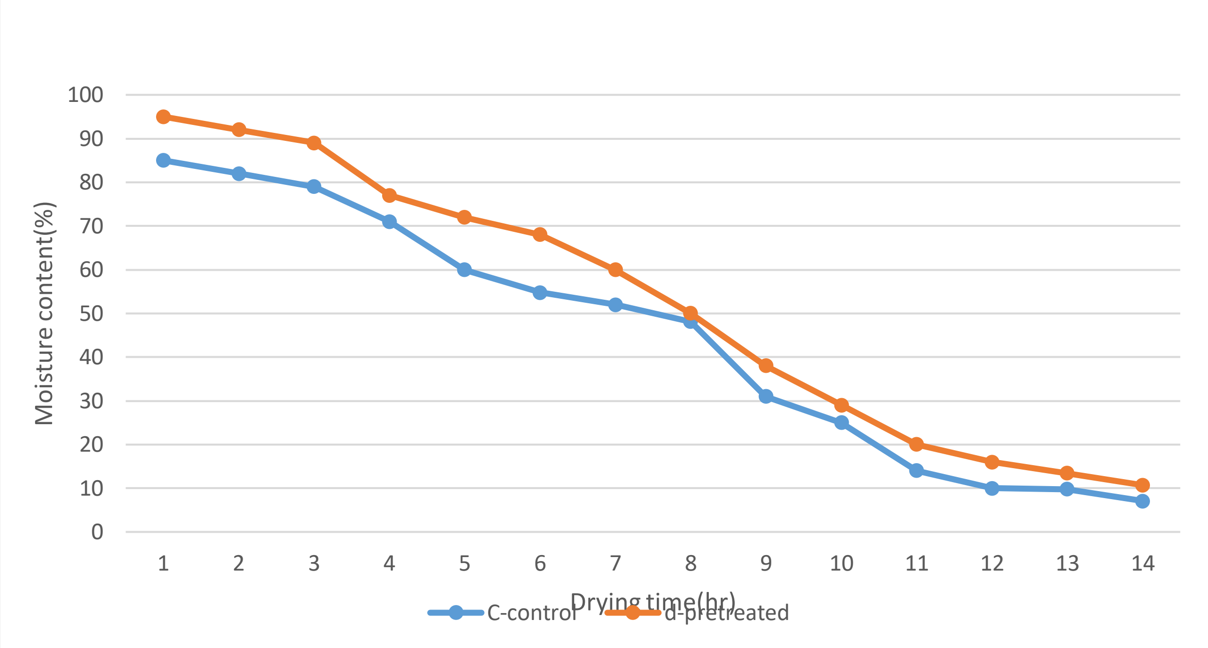

Figure 2. Drying rate of watermelon slices dried in oven. Key: C = control; D = pre-treated.

Consistent with previous findings [20], microwave drying reduced processing time by 50% compared to oven drying, but non-uniform heating remained a limitation.

Nutrient Retention

Table 1. Effect of drying method and pre-treatment on nutrient retention in watermelon slices

Treatment	Vitamin C (mg/g)	β-Carotene (mg/g)	Iron (mg/g)	Calcium (mg/g)
Oven-dried (Untreated)	24.53 ± 0.11^{d}	14.56 ± 0.09^{d}	0.81 ± 0.00^{b}	48.67 ± 0.10^{a}
Oven-dried (Pre-treated)	19.59 ± 0.10^{b}	10.77 ± 0.02^{b}	1.62 ± 0.01^{d}	45.25 ± 0.04^{a}
Microwave (Untreated)	21.67 ± 0.10^{c}	12.87 ± 0.04^{c}	0.77 ± 0.01^{a}	41.38 ± 0.04^{a}
Microwave (Pre-treated)	16.78 ± 0.04^{a}	8.56 ± 0.06^{a}	0.95 ± 0.01^{c}	42.77 ± 0.10^{a}

Values are mean ± SD. Superscripts (a–d) indicate statistical differences ($p < 0.05$) within columns.

Key findings: Oven drying preserved ~34% more vitamin C and ~41% more β-carotene than microwave drying. Ascorbic acid pre-treatment reduced vitamin retention by ~20% in both methods, likely due to thermal degradation [21]. Iron retention was highest in pre-treated oven-dried samples (1.62 mg/g), aligning with previous reports [22].

Total Soluble Solids (TSS) and Sensory Properties

TSS: Microwave drying increased TSS (88.47°Brix) due to rapid moisture expulsion and sugar concentration compared to oven drying (81.90°Brix) [23].

Table 2. Sensory evaluation scores (9-point hedonic scale)

Parameter	Oven-Dried (Untreated)	Microwave (Pre-treated)
Appearance	8.33 ± 0.72^{c}	6.73 ± 1.34^{a}

Taste	7.87 ± 1.19^b	6.27 ± 1.38^a
Overall Acceptability	8.00 ± 0.66^b	6.80 ± 0.94^a

Untreated oven-dried samples scored highest in all attributes ($p < 0.05$), attributed to Maillard reaction-enhanced flavors and uniform texture [23]. Pre-treated microwave samples developed slight bitterness, likely from ascorbic acid degradation at high temperatures [24].

Comparative Discussion

Nutrient–sensory trade-off: While microwave drying accelerated processing, it compromised vitamin retention and sensory quality. Oven drying better preserves heat-labile compounds due to milder thermal exposure. Pre-treatment paradox: Ascorbic acid improved mineral retention but degraded vitamins and sensory properties. Recommendation: Optimize concentration (<1%) or explore alternative pre-treatments such as blanching. Industry implication: Oven drying is optimal for nutrient retention in watermelon, while microwave drying may suit applications prioritizing speed over sensory quality, such as ingredient powders.

CONCLUSION

This study shows that while both oven and microwave drying can help extend the shelf life of watermelon, oven drying at 54°C clearly offers better results. It preserved more vitamin C and β-carotene, maintained good mineral content, and produced slices that consumers preferred in terms of taste, appearance, and overall acceptability. Although microwave drying was faster, it compromised nutrient stability and sensory quality. Interestingly, pre-treatment with ascorbic acid improved mineral retention but reduced vitamin stability, making it less desirable. Overall, Oven drying without chemical pre-treatment is recommended for optimal nutrient preservation and consumer acceptability in dehydrated watermelon products.

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