DOI: 10.36108/ujees/5202.70.0180
UNIOSUN Journal of Engineering and Environmental Sciences. Vol. 7 No. 1. March. 2025

Influence of Pretreatment and Temperature on Vitamin C Content of Dried African Star Apple Fruit

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Abstract The African star apple (Chrysophyllum africanum), a tropical fruit widely consumed for its sweet pulp has been found to be a rich source of vitamin C. Due to its seasonal nature and high spoilage rate, which contributes to environmental waste, processing is essential to make it available off-season. The fruits were washed, sorted, deseeded, and diced into 2 mm pieces, after which four selected pretreatment techniques [hot water blanching (80 °C for 3 min), steam blanching (100 °C for 1 min), salt solution (1:25 w/v), and sugar solution (60 ºBrix)] were applied. Untreated samples were used as control samples. All samples were then dried using an oven dryer and an electric dehydrator at temperatures of 45, 55, 65, and 75 °C, monitored at intervals until a constant weight was achieved. Throughout the experiment, the vitamin C content of the samples were measured using standard methods, similarly, the effect of pretreatment and drying temperature on the rate of vitamin C degradation was thoroughly assessed throughout the drying process. Significant differences were noticed in vitamin C retention across all pretreatment techniques employed. The vitamin C content of the fruit dropped from 56.38 mg/100 g in the fresh fruit to as low as 7.08 and 7.17 mg/100 g after oven drying and electric dehydration, respectively. Steam pretreatment at 55 °C yielded the best results in terms of vitamin C retention. Therefore, steam pretreatment has the potential to preserve the quality of dried fruits.

Keywords: African star apple, Pretreatment, Drying temperature, Drying method, Vitamin C

I. Introduction

Vitamin C is an essential antioxidant that plays a pivotal role in human health, contributing to immune function, collagen synthesis, and protection against oxidative stress [1]. Fruits and vegetables play a crucial role in meeting the daily vitamin C requirements for humans. However, like many other fruits, the African star apple is highly perishable, making preservation methods like drying essential to extend its shelf life and availability. While drying effectively reduces moisture content, making the fruit less susceptible to microbial spoilage, it can also lead to substantial nutrient losses, particularly heat-sensitive compounds like vitamin C [2].

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The extent of nutrient retention during drying is strongly influenced by pretreatment methods and drying temperature. Pretreatments such as blanching, soaking, or chemical treatments can mitigate the degradation of sensitive nutrients, while temperature optimization is critical to preserving bioactive compounds without compromising the drying process efficiency [3]. Despite the significance of these factors, there is limited research specifically focusing on the impact of pretreatment and temperature on the vitamin C content of dried African star apple fruit. Investigating these variables provides valuable insights into improving the nutritional quality of dried fruit products, supporting both consumer health and local food industries.

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II. Materials and Methods

The African star apple fruits used for this study were sourced for from a local farm in Iresa-Adu, Ogbomoso, Oyo State, Nigeria

A. Sample Preparation

African star apple fruits were washed with distilled water to remove all debris and extraneous materials, then sorted to remove bruised, diseased and unwholesome fruits after which cutting was done to remove the flesh and seeds of the wholesome fruits. The pulp was then cut into small pieces of 2 mm which was subjected to various pretreatment techniques.

B. Sample Pretreatment

Samples were pretreated using four different methods which were hot water blanching (80 ℃ for 3 min), steam blanching (100 ℃ for 1 min), salt (1:25 w/v for 5 min) and sugar (60 ºBrix for 5 min) according to [4] and [5].

C. Drying Procedure

The drying process was conducted using 0.35 kg of freshly pretreated and untreated African star apple pulps which was spread out in perforated trays. Samples were dried at temperatures of 45, 55, 65 and 75 ℃ using two different drying methods; an oven dryer (DHG-9240A, UK) and an electric dehydrator both designed to dry food materials under controlled conditions. While the oven dryer can operate at high temperatures – up to 260 ℃, the dehydrator only operates between 35 and 75 ℃. The dehydrator is also equipped with built-in fans for even circulation of air around the food, whereas, the oven dryer relies on convection current which is less even.

During the experiment, both dryers were set at each drying temperature at a time and allowed to work continuously for one hour to allow for an equilibrium in air circulation before placing in the samples. After loading the samples, they were weighed at 1-hour intervals throughout the drying process, during which the corresponding vitamin C degradation was also measured. Weighing continued until a constant weight was reached for three consecutive measurements, indicating negligible weight loss [6]. The experiments were performed in triplicate, and the average results were documented. Following the drying process, the samples were stored in ziplock bags for further analysis.

D. Vitamin C Determination

Aliquots of the samples in oxalic acid solution were titrated with standardized sodium 2,6-dichlorophenol dye until a faint pink color persisted for 5 to 10 sec. Ten grams of each African star apple sample were weighed and macerated in a porcelain dish. Twenty-five milliliters (25 cm^3) of distilled water were added to the macerated sample to form a solution. Twenty milliliters (20 cm^3) of this solution were pipetted into a 100 cm^3 volumetric flask, which was then filled to the mark with 0.4% oxalic acid and filtered through Whatman filter paper to clarify the solution. Ten milliliters (10 cm^3) of the filtrate (aliquot) were pipetted, and 15 cm^3 of the 0.4% oxalic acid were mixed with the filtrate. This mixture was titrated in a 50 cm^3 Erlenmeyer flask with the dye until a faint pink endpoint was reached, lasting 5 to 10 s. The result was presented as mg/100 g vitamin C using the procedure described [7].

E. Statistical Analysis

All experiments were conducted in triplicates, and the data obtained were subjected to statistical analysis. The results were expressed as means ± standard error (SE). Significant differences in measurements were assessed using Analysis of Variance (ANOVA) with the SPSS statistical software (SPSS 20.0 for Windows; SPSS Inc., Chicago, IL, USA). The significance of the differences between the means was determined using the Duncan Multiple Range Test, and differences were considered significant at $p < 0.05$.

III. Results and Discussion

A. Effect of Pretreatment and Drying on Vitamin C

Figures 1 and 2 illustrate the impact of pretreatment and drying on the vitamin C content of African star apple samples. A deficiency in vitamin C (ascorbic acid) can result in scurvy a condition marked by weakness and tooth loss [8]. At the least drying temperature of 45 ℃, the vitamin C values measured across the various samples ranged from 56.38 mg/100 g in the fresh sample to 7.67, 8.78, 7.154, 7.08, 8.25 mg/100 g for oven dried African star apple and 8.11, 8.95, 7.49, 7.17, 8.67 mg/100 g for electrically dehydrated African star apple in samples pretreated with steam, sugar, salt, hot water and control samples, respectively. While the values of vitamin C measured at the highest. drying temperature of 75 ℃ ranged from 56.38 mg/100 g in the fresh sample to 5.99, 6.84, 6.72, 5.54, 6.92 mg/100 g for oven dried African star apple and 5.87, 6.19, 6.10, 5.407 and 6.237 mg/100 g for electrically dehydrated African star apple in samples pretreated with steam, sugar, salt, hot water and control samples, respectively.
It was observed that vitamin C degraded the most in samples pretreated with hot water. This is because some vitamin C content leeched into the blanching water during pretreatment. The sample that retained vitamin C the most were the control samples dried at 45 ℃ (9.99 mg/100 g) and 55 ℃ (9.25 mg/100 g). Although not much differences were noticed between both drying methods, the oven dried control samples seemed to retain a little more vitamin C compared with the electric dehydration method. Samples pretreated with steam and sugar, and dried at 45 and 55 °C also retained more vitamin C than samples pretreated with salt and hot water.

According to [9] sugar may have protective effect against vitamin C degradation by modifying the drying atmosphere or food matrix during the drying process. The findings generally align with the results of [10], who stated that prolonged heating and higher temperatures have a more detrimental impact on vitamin C content, as it is a heat-labile vitamin. From Figures 1 and 2, a downward curve depicting a noticeable decrease in the vitamin C content of the fruit can be seen for both drying methods. The oven drying method retained more vitamin C when compared to the electric method of drying although with not much significant difference.

B. Degradation Kinetics of Vitamin C in African Star Apple Samples

Figures 3 and 4 shows the plot of concentration of vitamin C against time and the rate constant k was obtained as a slope of the linear graph. Tables 1 and 2 shows the constant and half-life ($t_{1/2}$) for all the pretreatments. It can be observed from the tables that the degradation rate increased with temperature increase. Additionally, the correlation coefficient values were greater than 0.9 in all cases, confirming the assumption that degradation followed first-order kinetics [11]. The mean value of the rate constant for oven drying was 0.2458, 0.2138, 0.1974 and 0.2396 min^{-1} for temperatures of 45, 55, 65 and 75 ℃, respectively while that of electric drying was 0.2452, 0.2146, 0.1310 and 0.2368 min^{-1} for temperatures of 45, 55, 65 and 75 ℃, respectively.
From Tables 1 and 2, it can be observed that degradation rates generally increased with temperature for all pretreatments, as indicated by

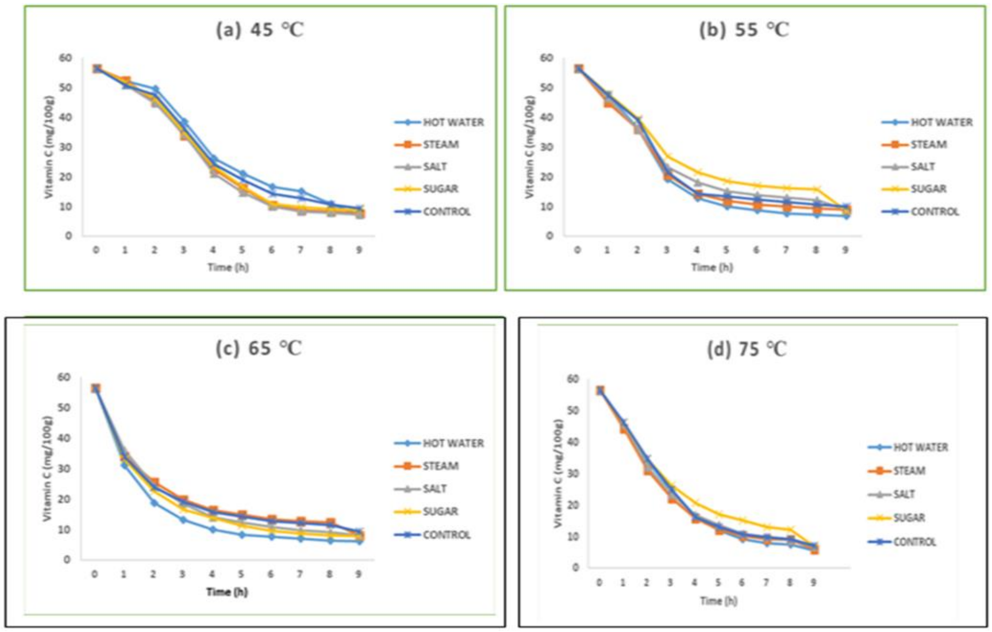

Figure 1a-d: Graph of Vitamin C Content against Time for Oven Drying at Different Temperature

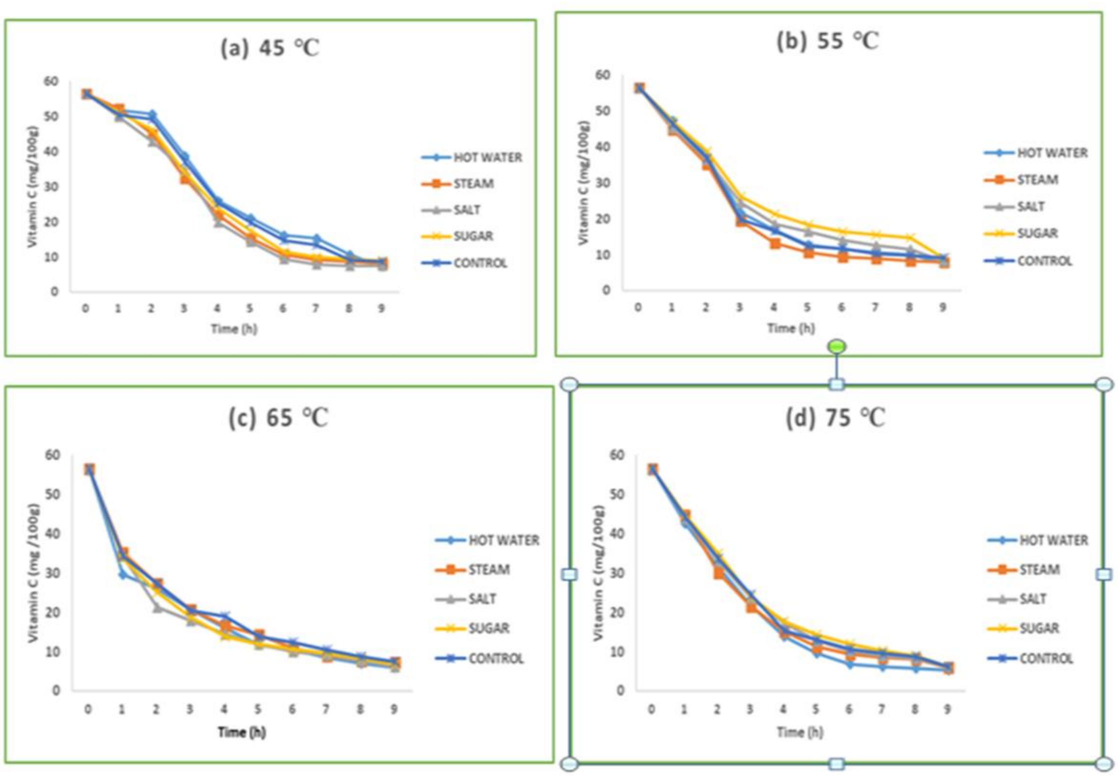

Figure 2a-d: Graph of Vitamin C Content against Time for Electrical Dehydration at Different Temperatures

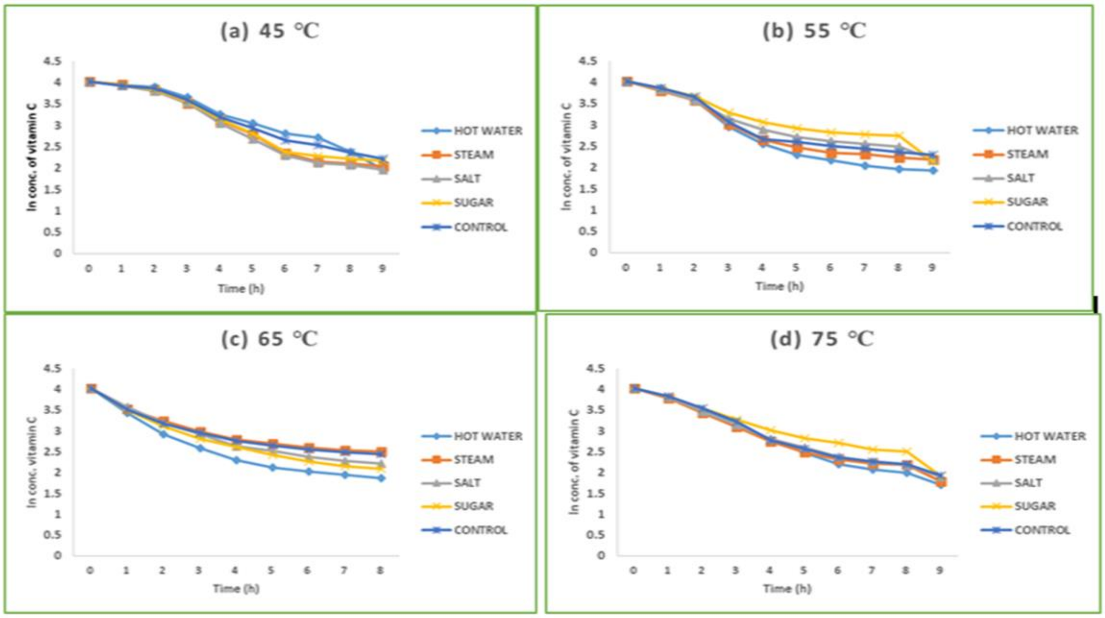

Figure 3a-d: Graph of Vitamin C Degradation at Different Oven Drying Temperatures

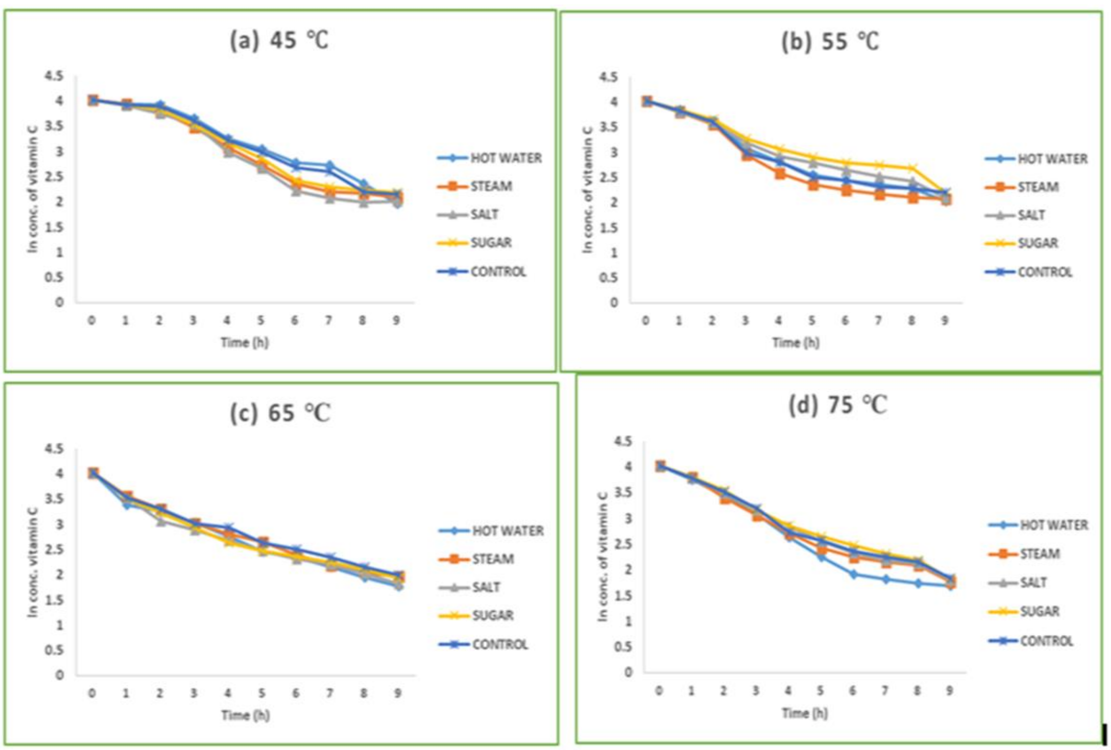

Figure 4a-d: Graph of Vitamin C Degradation at Different Electrical Drying Temperatures

Table 1: Degradation Rate of Vitamin C and Half-life of Dried African Star Apple at Different Oven Drying Temperatures.

Temperature (℃)	Pretreatment	Regression equation for degradation	R^2	t ½ (min)
45 ℃				
	Steam	y = -0.18x + 3.70	0.91	233.64
	Sugar	y = -0.19x + 3.98	0.94	222.42
	Salt	y = -0.20x + 3.91	0.94	208.98
	Hot Water	y = -0.23x + 3.53	0.86	182.40
	Control	y = -0.17x + 3.66	0.89	240.42
55 ℃				
	Steam	y = -0.22x + 3.85	0.91	189.90
	Sugar	y = -0.21x + 3.64	0.90	201.90
	Salt	y = -0.20x + 3.69	0.91	205.86
	Hot Water	y = -0.23x + 4.22	0.97	178.50
	Control	y = -0.21x + 3.88	0.88	201.90
65 ℃				
	Steam	y = -0.24x + 3.91	0.96	171.12
	Sugar	y = -0.21x + 3.98	0.97	196.20
	Salt	y = -0.24x + 3.93	0.97	175.50
	Hot Water	y = -0.26x + 3.90	0.91	161.22
	Control	y = -0.22x + 4.14	0.98	186.48
75 ℃				
	Steam	y = -0.26x + 4.16	0.96	159.36
	Sugar	y = -0.25x + 4.14	0.95	169.74
	Salt	y = -0.27x + 4.15	0.96	155.76
	Hot Water	y = -0.27x + 3.98	0.98	155.76
	Control	y = -0.24x + 3.95	0.96	174.00

Table 2: Degradation Rate of Vitamin C and Half-life of Dried African Star Apple at Different Electrical Dehydration Temperatures.

Temperature (℃)	Pretreatment	Regression equation for degradation	R^2	t ½ (min)
45 ℃				
	Steam	y = -0.22x + 3.80	0.97	186.48
	Sugar	y = -0.19x + 3.96	0.95	222.42
	Salt	y = -0.20x + 3.94	0.97	200.94
	Hot Water	y = -0.23x + 3.93	0.94	182.40
	Control	y = -0.22x + 3.88	0.91	192.54
55 ℃				
	Steam	y = -0.24x + 3.85	0.90	177.00
	Sugar	y = -0.22x + 3.72	0.94	193.44
	Salt	y = -0.22x + 3.70	0.95	187.32
	Hot Water	y = -0.23x + 3.76	0.97	179.28
	Control	y = -0.21x + 3.79	0.97	198.96
65 ℃				
	Steam	y = -0.24x + 3.88	0.96	171.84
	Sugar	y = -0.23x + 3.93	0.98	183.24
	Salt	y = -0.23x + 3.92	0.98	178.50
	Hot Water	y = -0.25x + 3.870	0.95	167.70
	Control	y = -0.23x + 4.180	0.98	178.50
75 ℃				
	Steam	y = -0.25x + 4.128	0.96	165.06
	Sugar	y = -0.24x + 4.135	0.96	173.28
	Salt	y = -0.23x + 4.219	0.97	178.50
	Hot Water	y = -0.27x + 4.128	0.95	155.16
	Control	y = -0.23x + 3.906	0.97	177.72

the negative slope becoming larger while the half-life decreases with increasing temperature, meaning samples degrade faster at higher temperatures, though the effectiveness of different pretreatments varies with temperature, with hot water consistently leading to faster degradation rates across all temperatures. This aligns with the observations reported by [11], where the degradation of vitamin C in Lathyrus sativus L flour increased with longer drying times and higher temperatures. For oven drying, Figure 3a reveals that all pretreatments showed a gradual degradation in their vitamin C values over time at 45 ℃ with hot water pretreated sample decreasing most rapidly after the midpoint while the sugar pretreated sample and control sample maintained higher values of 2.17 and 2.22, respectively by the end of the time period.

With an increase in temperature to 55 ℃ shown in Figure 3b, all samples exhibited a more pronounced degradation in values. Hot water pretreated sample dropped sharply from 4.03 to 1.92 indicating a rapid decline in this pretreatment. Steam pretreated sample declined steadily from 4.03 to 2.18, maintaining better values than hot water pretreatment while the control sample showed a consistent decline, finishing at 2.30, performing slightly better than sugar and salt pretreatments at the end.

Vitamin C degradation became steeper as the temperature increased to 65 ℃ as can be seen in Figure 3c. Steam pretreated sample and control sample retained the highest values of 2.51 and 2.44, respectively indicating they are the most resilient pretreatment at higher temperatures. Like in other temperatures, hot water pretreated sample again showed the most significant decline from 4.03 to 1.86. Furthermore, Figure 3d show that vitamin C degradation became more pronounced at the highest temperature of 75 ℃, hot water pretreatment showed the steepest decline once again, while salt, sugar, and control samples showed similar final values, all performing better than hot water pretreatment but still experiencing significant declines. Overall, hot water pretreatment showed the most rapid decline in vitamin C across all temperatures, particularly at 65 and 75 ℃. Steam and salt pretreated samples performed similarly across all temperatures, with steam pretreated sample showing slightly better resilience at 65 ℃ while sugar pretreated and control samples consistently performed similarly, especially at higher temperatures, with relatively stable but still declining values.

African star apple samples electrically dehydrated at 45 ℃ (Figure 4a) show that all pretreatments (hot water, steam, salt, sugar) and control samples showed a gradual degradation over time with hot water pretreatment showing the sharpest drop from 4.03 to 1.97, while sugar pretreated sample and the control sample maintained slightly higher levels of 2.19 and 2.15, respectively at the end compared to others. All pretreatments again exhibited a decreasing trend at 55 ℃ as shown in Figure 4b with hot water pretreated sample showing the most decrease from 4.03 to 2.02 indicating a substantial degradation, especially between the 5th and 9th time points, while sugar pretreated and control samples again perform similarly and maintain higher levels of 2.19 and 2.20, respectively.

With increasing temperature, all pretreated samples show a steeper decline compared to the lower temperatures. Hence, Figure 4c shows that at 65 ℃, hot water pretreated sample declined sharply from 4.03 to 1.77; the steepest decline at this temperature. The control sample experienced the slowest decline maintaining slightly higher values compared to other pretreatments. Figure 4d shows that degradation became more pronounced across all pretreatments at 75 ℃, with hot water once again showing the steepest decline from 4.03 to 1.68 while steam, salt, sugar pretreated and control samples all showed similar trends, ending within a close range. Overall, it was observed that hot water pretreated samples consistently showed the sharpest decline in vitamin C degradation across all temperatures, indicating a strong sensitivity to heat. Steam, salt, and sugar pretreatments exhibited similar trends but tend to retain vitamin C slightly better when compared to hot water as temperature increased. The control sample showed the least fluctuation and maintained a relatively steady degradation across all temperatures, mirroring the sugar pretreatment closely.

C. Statistical result of vitamin C as affected by pretreatment and drying temperatures

Table 3 illustrates the increase in the degradation rate of vitamin C content in dried African star apple samples with increasing drying temperature. The findings of [12] established that, drying foods at higher temperatures leads to vitamin C loss, as it is heat-labile. In their research, it was observed that drying temperatures above 60 °C caused significant vitamin C losses during the drying of cauliflower. Similarly, [13] suggested that vitamin C losses in many drying processes could be attributed to the oxidation of vitamin C at high temperatures.

The degradation of vitamin C across all pretreated samples and both drying methods was consistent, indicating that hot-air drying leads to vitamin C degradation in fruits. It is also observed that the control samples retained higher vitamin C content when compared with all the pretreated samples, this according to [14] is probably due to enzymatic and chemical degradation during the drying process.

IV. Conclusion

The pulp of African star apple was pretreated and dried using an oven dryer and an electric dehydrator at four different temperatures, drying time ranged from 7 to 8 h. Vitamin C was observed to degrade with increase in temperature owning to the fact that it is heat-labile. A significant difference was observed in the residual vitamin C content of African star apple for all pretreatments and drying temperatures. Steam pretreatment of the African star apple sample followed by oven drying at 55 °C resulted in the highest vitamin C retention.

Table 3: Statistical analysis of vitamin C content of dried African star apple fruit

Sample	Oven	Electric
Fresh	56.38	56.38
45 °C		
Hot water	14.16 ± 0.07^{d}	14.35 ± 0.06^{a}
Steam	15.34 ± 0.06^{a}	16.22 ± 0.02^{a}
Salt	14.31 ± 0.17^{ab}	14.98 ± 0.11^{c}
Sugar	17.26 ± 0.02^{e}	17.31 ± 0.09^{b}
Control	18.50 ± 0.24^{a}	17.34 ± 0.16^{e}
55 °C		
Hot water	13.74 ± 0.08^{b}	15.13 ± 0.05^{e}
Steam	17.72 ± 0.01^{cd}	17.67 ± 0.01^{d}
Salt	16.91 ± 0.10^{c}	16.17 ± 0.12^{a}
Sugar	16.94 ± 0.01^{ab}	17.45 ± 0.07^{c}
Control	19.98 ± 0.14^{ab}	18.10 ± 0.09^{d}
65 °C		
Hot water	12.40 ± 0.09^{a}	11.81 ± 0.08^{e}
Steam	16.16 ± 0.11^{ab}	14.25 ± 0.03^{c}
Salt	16.05 ± 0.09^{e}	12.33 ± 0.12^{cd}
Sugar	15.82 ± 0.01^{d}	13.71 ± 0.02^{a}
Control	18.62 ± 0.21^{d}	14.74 ± 0.17^{e}
75 °C		
Hot water	11.07 ± 0.10^{d}	10.81 ± 0.01^{a}
Steam	11.97 ± 0.03^{e}	11.74 ± 0.01^{e}
Salt	13.43 ± 0.19^{d}	12.21 ± 0.11^{e}
Sugar	13.68 ± 0.12^{b}	12.38 ± 0.07^{d}
Control	13.85 ± 0.25^{a}	12.47 ± 0.09^{b}

Means with different superscript within the columns are significantly different ($P < 0.05$)
Source: Authors' findings.

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