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Storage effects on the quality of osmotically dehydrated cauliflower

Vijai Kumar, Neelesh Chauhan, Jaivir Singh, Suresh Chandra, BR Singh and Vivak Kumar

Department of Agricultural Engineering, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

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Corresponding Author: Vijai Kumar

Abstract

The Dehydration is a widely adopted method for extending the shelf life of vegetables and ensuring their availability throughout the year. This study evaluated the impact of four pre-treatments Control (untreated), Blanching, Citric Acid (0.25%), and Potassium Metabisulfite (KMS, 0.25%) on the physico-chemical quality of osmotic dehydrated cauliflower (*Brassica oleracea* botrytis) stored for 120 days under ambient conditions. Fresh cauliflower was processed into dehydrated form and samples were analyzed at 0, 30, 60, 90, and 120 days for pH, moisture content, titratable acidity, optical density, ash content, and ascorbic acid levels. The Results showed a gradual decline in pH and ascorbic acid across all treatments, with the control group deteriorating most rapidly. KMS-treated samples exhibited minimal pH reduction (from ~6.0 to ~5.7) and superior ascorbic acid retention, indicating strong preservation potential. The Citric acid treatment maintained a lower pH due to its acidic nature and demonstrated effective antimicrobial action. The Blanching offered better quality retention than the control but was less effective than chemical treatments. The Moisture content increased over time in all treatments, likely due to packaging permeability and ambient humidity, with KMS and citric acid showing the least gain. Titratable acidity increased during storage, particularly in untreated samples, reflecting microbial and enzymatic activity. Optical density decreased steadily, with KMS-treated powders retaining better visual quality. The Ash content showed slight reductions across treatments, with chemical treatments providing better mineral retention than control samples. Overall, potassium metabisulfite proved most effective in preserving the nutritional, chemical, and visual quality of cauliflower during storage. The use of KMS or citric acid as practical pre-treatments for commercial dehydration and storage, ensuring extended shelf life and enhanced market value.

Keywords: Cauliflower, Potassium metabisulfite (KMS), pre-treatment, storage stability, ascorbic acid retention

1. Introduction

Cauliflower (*Brassica oleracea* var. botrytis), a member of the Brassicaceae family, is a widely consumed cruciferous vegetable in India, valued for its nutritional content, versatility, and economic importance. It is rich in dietary fiber, vitamins C and K, glucosinolates, and antioxidants-making it a functional food with potential health benefits such as cancer prevention and glycemic control (Singh *et al*., 2017; Picchi *et al*., 2020; Sharma *et al*., 2024) [34, 20, 31]. However, cauliflower is highly perishable due to its high moisture content (approximately 85-90%), which makes it prone to rapid respiration, enzymatic browning, microbial decay, and post-harvest losses—estimated at 30-40% in India (Rai & Yadav, 2020; Menjura-Camacho & Villamizar, 2004) [22, 18]. These losses are further exacerbated by inadequate processing and storage infrastructure in tropical and subtropical climates. Additionally, cauliflower by-products like stems and leaves have been utilized in value-added products such as biscuits and extruded snacks, offering sustainable avenues to reduce waste while enhancing nutritional value (Wani & Sood, 2014; Ribeiro *et al*., 2015; Lakshmi *et al*., 2017) [40, 27, 16]. Among the emerging preservation techniques, osmotic dehydration (OD) presents a particularly attractive low-energy method. OD involves immersing food materials in hypertonic solutions to partially remove water, reduce water activity, and extend shelf life while minimizing thermal damage and retaining key nutrients and sensory properties (Lenart & Flink, 1984; Rastogi *et al*., 2002) [17, 26]. This technique is especially relevant under Indian agro-climatic conditions, where high ambient temperatures and humidity accelerate spoilage. The osmotic process is governed by complex mass transfer mechanisms mainly water loss and solid gain which depend on variables such as temperature, immersion time, solution concentration, and agitation (Chandra & Das, 2008) [4]. Moreover, it is crucial to evaluate the retention of physicochemical and nutritional parameters like color, texture, ascorbic acid content, pH, optical density, and antioxidant activity, which are key to consumer acceptance and marketability (Kowalska *et al*., 2008) [11]. Despite numerous international studies, research on osmotic dehydration of cauliflower under Indian environmental conditions remains limited. Cauliflower is an important vegetable crop in India, valued for its high nutritional content and economic significance. However, its high moisture content and perishable nature result in substantial post-harvest losses, estimated at 30-40%, particularly under tropical and subtropical Indian conditions where high temperature and humidity accelerate spoilage. Existing preservation methods such as refrigeration and modified atmosphere packaging, while effective, are costly, energy-intensive, and often inaccessible to small-scale farmers.

Osmotic dehydration is recommended as a processing method to obtain better quality of food products (Chandra *et al*., 2013) [5]. Osmotic dehydration offers a low-energy, cost-effective alternative that can reduce water activity, extend shelf life, and retain nutritional and sensory qualities. Despite its proven potential globally, limited research has been conducted on optimizing osmotic dehydration for cauliflower under Indian agro-climatic conditions. This study aiming to enhance marketability, reduces losses, and improve value addition in the cauliflower supply chain.

2. Materials and Methods

2.1 Experimental Location: The experiment of osmotic dehydration, storage quality of cauliflower and packaging was carried out at the Department of Agricultural Process and Food Engineering, (College of Technology), Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh.

2.2 Raw Material Procurement and Preparation: The Fresh, mature, and uniform cauliflower heads (*Brassica oleracea* var. botrytis) were procured from the local market, ensuring the absence of visible blemishes, mechanical damage, or microbial infection. The curds were washed thoroughly under running water to remove dirt and adhered foreign matter, and then manually trimmed into uniform-sized florets to minimize variability in mass transfer during dehydration.

2.3 Physico-Chemical Properties of Dehydrated Cauliflower

2.3.1 Determination of pH: pH, a measure of hydrogen ion concentration, was calculated as the negative logarithm of the hydrogen ion concentration using the formula:

$$pH = -\log(H^+)$$

where H^+ is expressed in grams per liter. The pH of cauliflower samples was determined as per the method outlined by Ranganna (2001) [25] using a digital pH meter (Systronics µ pH system-361). The instrument was calibrated with standard buffer solutions at pH 7.0 and 4.0 before use. For analysis, 10 mL of the sample was mixed with 100 mL of distilled water, filtered, and the temperature of the meter was adjusted to match the test solution. The pH mode was selected, the electrode immersed, and the stabilized reading recorded.

2.3.2 Acidity: The titratable acidity was determined by blending 10 g of the sample with 100 mL distilled water, followed by filtration. A 10 mL aliquot of the filtrate was titrated against 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator. The results were expressed as a percentage of citric acid (for fruits) or malic acid (for vegetables), depending on the nature of the sample. This method is widely adopted for fruit and vegetable analysis (Ranganna, 2001; Srivastava & Kumar, 2016; AOAC, 2016) [25, 37, 3].

2.3.3 Optical Density: Optical density, an indicator of browning intensity and color changes, was measured using a UV-Vis spectrophotometer. An extract of the sample was prepared using distilled water or ethanol, and absorbance was recorded at 420 nm. The values were expressed in absorbance units (AU). This method is commonly used for quality assessment of processed plant products (Thimmaiah, 1999; Kirk & Sawyer, 1991) [38, 10].

2.3.4 Ascorbic Acid: The vitamin C (ascorbic acid) content was estimated using the dye titration method. Samples were extracted with 3% metaphosphoric acid solution and titrated against a standard solution of 2,6-dichlorophenol indophenol (DCPIP) until a persistent pink endpoint appeared. The ascorbic acid content was expressed as mg per 100 g of sample. This method is standard for vitamin C determination (Ranganna, 2001; AOAC, 1990; Thimmaiah, 1999) [25, 1, 38].

2.3.5 Ash Content: Ash content was determined by incinerating the sample in a muffle furnace (TANCO model). Preheated crucibles with lids were maintained at 525°C overnight, cooled, and weighed. Approximately 10 g of the sample was taken and incinerated at 525°C for six hours until a constant weight was achieved. The remaining residue was weighed after cooling in a desiccator, and ash percentage was calculated as:

$$\text{Ash content (\%)} \frac{\text{final weight of ash}}{\text{initial weight of sample}} \times 100$$

2.3.6 Determination of Bone-Dry Matter: To determine bone-dry matter, the sample weight was corrected using the moisture content. The formula used was:

$$\text{Wd} = \frac{Weight\ of\ Wet\ Sample\ (g)}{1 + \left(\frac{Moisture\ content}{100}\right)}$$

Where,
Wi = Initial weight of the sample, g
Mc = Moisture content of the sample,% (w.b.)
This method ensures precise quantification of dry matter in agricultural produce (AOAC, 2016; Ranganna, 2001) [3, 25].

3. Results and Discussion

3.1 Physico-Chemical Properties of Dehydrated Cauliflower

The quality of dehydrated Cauliflower was assessed by analyzing pH, moisture, acidity, optical density, ash, and ascorbic acid content. These parameters indicate nutritional value, shelf life, and product stability, helping ensure that drying preserves key qualities and enhances storage and usage potential.

3.2 Effect of Storage on pH of Cauliflower

Figure 1 illustrates the change in pH of Cauliflower over a 120-day storage period across four treatments: Control (untreated), Blanched, Citric Acid, and Potassium Metabisulfite (KMS). A consistent decline in pH was observed for all treatments, primarily due to oxidative reactions and microbial activity during storage (Fellows, 2009) [6]. The control sample exhibited the most pronounced drop, highlighting its susceptibility to degradation without any preservation. Blanched samples maintained better pH stability, likely due to enzyme inactivation and reduced microbial load achieved through heat treatment (Ramaswamy & Marcotte, 2006) [23]. The citric acid-treated cauliflower, having started with a lower initial pH (5.3), displayed a consistent decrease, emphasizing citric acid's natural acidifying and antimicrobial role.

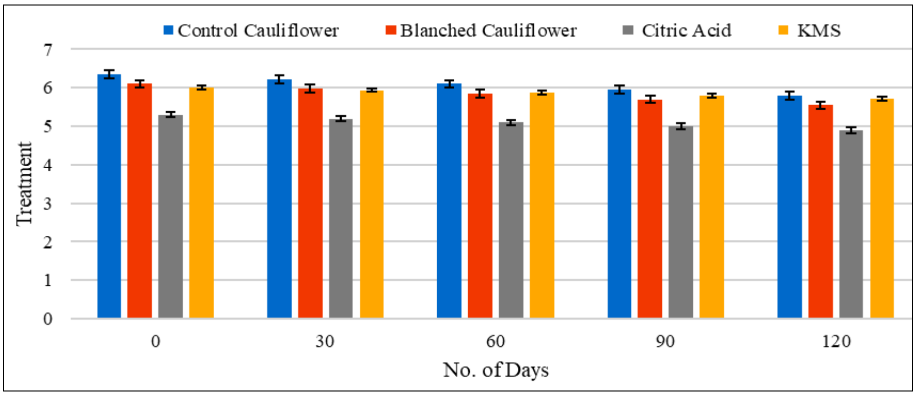

Fig 1: Effect of Storage on pH of Cauliflower Under Different Treatments

However, the KMS-treated sample exhibited the highest stability in pH, declining only slightly from 6.0 to 5.7 over 120 days, reflecting the efficacy of potassium metabisulfite as a strong antioxidant and preservative (Jay, 2000) [8]. These findings align with prior research that confirms the effectiveness of chemical preservatives like KMS in maintaining the chemical integrity and shelf stability of dried vegetable powders during extended storage periods (Karuna *et al*., 2018; Yadav *et al*., 2021) [9, 41].

3.3 Effect of Moisture content on storage of Cauliflower

The Figure 2 show a progressive increase in the moisture content of Cauliflower over a 120-day storage period across all treatments. Initially, moisture levels were below 5%, ideal for product stability. However, due to the hygroscopic nature of dehydrated powders, moisture content increased with time (Kumar *et al*., 2019) [13]. The untreated control sample absorbed the most moisture, rising to 7.10%, while the KMS-treated sample had the least increase, reaching only 5.25% at 120 days. Treatments with citric acid and blanching also slowed moisture gain.

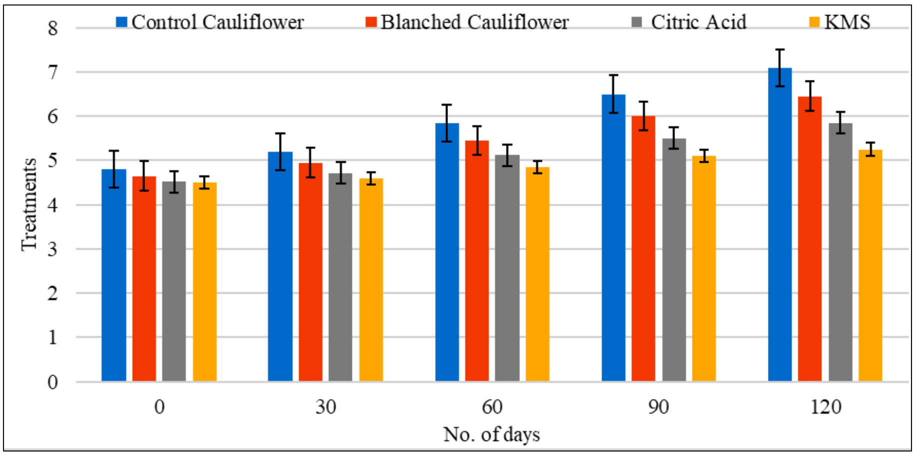

Fig 2: Effect of Storage on Moisture content of Cauliflower Under Different Treatments

These additives help reduce enzymatic browning and may alter surface characteristics, limiting moisture uptake (Sagar & Suresh Kumar, 2010) [28]. The findings support earlier studies showing that pre-treatments and preservatives improve storage stability of dehydrated vegetables by reducing moisture absorption (Singh *et al*., 2021; Ranganna, 2001) [32, 25].

3.4 Effect of Storage on Acidity of Cauliflower

The acidity of Cauliflower increased progressively during 120 days of storage across all treatments Control, Blanched, Citric Acid, and Potassium Metabisulfite (KMS) as shown in Figure 3. The control sample exhibited the lowest acidity throughout, while the citric acid-treated sample consistently recorded the highest due to the initial acid addition and its preservative properties. The gradual rise in acidity is attributed to ongoing biochemical reactions and limited microbial activity during storage. Citric acid treatment proved most effective in maintaining high acidity levels, which contributes to enhanced microbial stability (Sapers *et al*., 2001) [29]. The KMS treated samples showed moderate acidity increases, benefiting from the compound's antioxidative and antimicrobial nature (Jaiswal *et al*., 2010) [7]. The Blanched and control samples followed a similar trend but with slightly lower acidity values, reflecting natural enzymatic and microbial activity (Rai *et al*., 2015; Singh & Chauhan, 2018) [21, 35].

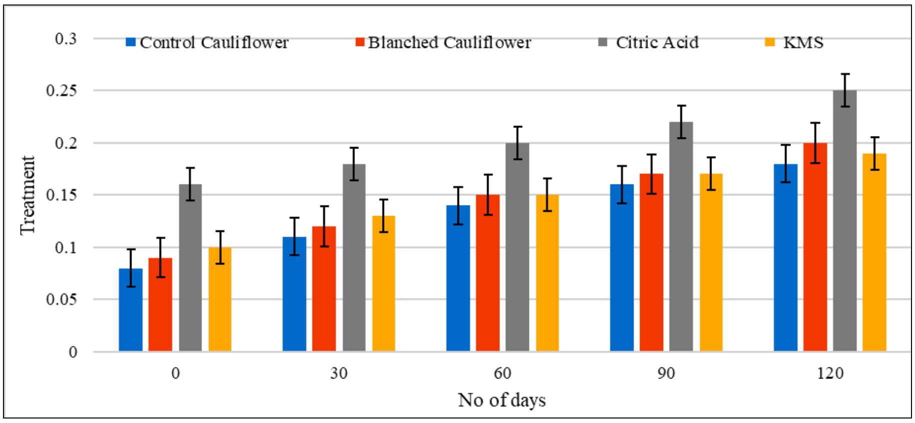

Fig 3: Effect of Storage on Acidity of Cauliflower Under Different Treatments

These results suggest that acidification, particularly with citric acid, improves shelf stability and safety of dried vegetable powders during long-term storage.

3.5 Effect of Storage on optical density of Cauliflower

The Optical Density (OD) serves as a reliable indicator of color stability and browning in dried vegetable powders during storage. As shown in Figure 4, OD values of Cauliflower increased progressively over 120 days across all treatments control, blanched, citric acid, and potassium metabisulfite (KMS). The control samples exhibited the most significant rise (from 0.16 to 0.40), indicating intense browning due to ongoing enzymatic and non-enzymatic reactions. The Blanched samples showed a moderated increase in OD (0.12 to 0.33), owing to enzyme inactivation through heat treatment, primarily of polyphenol oxidase (Kumar *et al.*, 2012) [12]. The Citric acid-treated samples demonstrated better control over browning (0.10 to 0.26), benefiting from the antioxidant properties of the acid (Sapers *et al.*, 2001) [30].

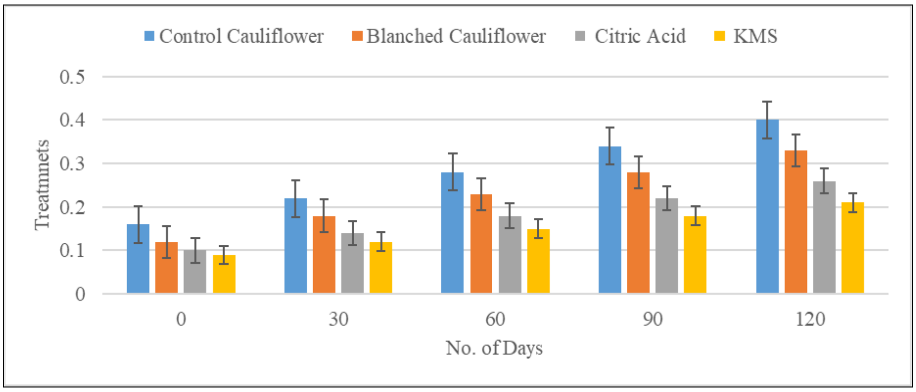

Fig 4: Effect of Storage on Optical Density of Cauliflower Under Different Treatments

The least OD change was observed in the KMS-treated samples (0.09 to 0.21), highlighting the superior efficacy of sulfiting agents in inhibiting browning and maintaining visual quality (Jaiswal *et al.*, 2010; Kumar *et al.*, 2016; Sogi *et al.*, 2003) [7, 36]. These findings underscore the importance of chemical pretreatments in enhancing the shelf stability and aesthetic appeal of dehydrated Cauliflower. The lowest OD values throughout storage were observed in samples treated with KMS (Potassium Metabisulphite), followed by those treated with citric acid, reflecting their role in controlling oxidative and enzymatic browning due to their antioxidant and preservative properties (Jaiswal *et al.*, 2010; Sapers *et al.*, 2001) [7, 29]. These results indicate that chemical treatments, particularly with KMS and citric acid, are effective in minimizing quality deterioration and preserving the visual and functional qualities of Cauliflower during storage.

3.6 Effect of Storage on ash content of Cauliflower

The Ash content indicates the total mineral composition of food products. The Cauliflower samples control, blanched, citric acid-treated, and KMS-treated showed a gradual decline in ash content during 120 days of storage (Fig. 5). The initial ash content ranged from 5.61% to 5.82%, aligning with standard values for dehydrated cauliflower (Sagar & Suresh, 2010) [28]. Over time, a slight reduction in ash was noted across all treatments, likely due to oxidative degradation or leaching of minerals under ambient conditions (Kumar *et al.*, 2012) [14]. The Control samples retained the highest ash content throughout, while KMS-treated samples showed the lowest.

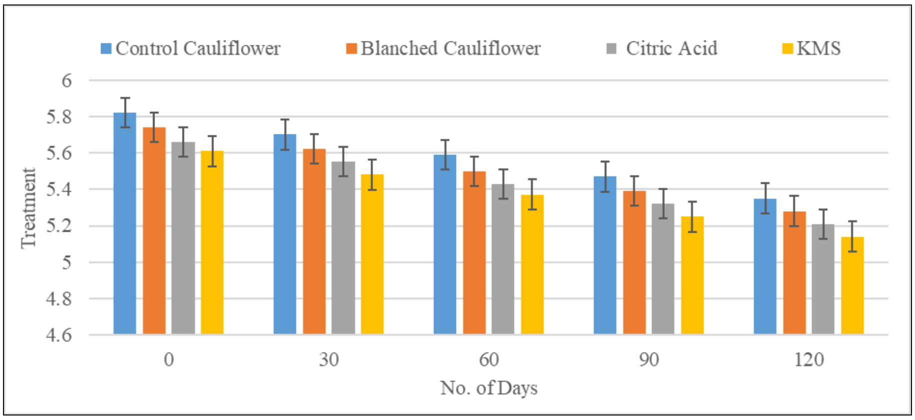

Fig 5: Effect of Storage on ash content of Cauliflower Under Different Treatments

However, both citric acid and KMS treatments demonstrated better retention compared to blanched samples alone, indicating a potential protective effect of chemical preservatives (Ramesh *et al*., 2001; Verma & Gupta, 2015) [14, 39]. Although the reduction was minor, these trends highlight a trade-off between enhanced shelf-life and nutrient retention, especially in chemically treated samples (Sapers & Simmons, 2001; Jaiswal *et al*., 2010) [29, 7].

3.7 Effect of Storage on Ascorbic Acid Content of Cauliflower

Ascorbic acid (Vitamin C) is an essential water-soluble vitamin with strong antioxidant properties, but it is highly sensitive to heat and prolonged storage. Figure 6 shows the decline of ascorbic acid in all four treatments over time. As storage progressed, vitamin C levels consistently decreased. Among the treatments, KMS and citric acid proved most effective in slowing this loss, mainly due to their preservative and antioxidant functions that protect the vitamin from oxidative damage. These findings are in line with Jaiswal *et al*. (2010) [7], who reported that ascorbic acid is particularly vulnerable to degradation when exposed to oxygen, heat, and light.

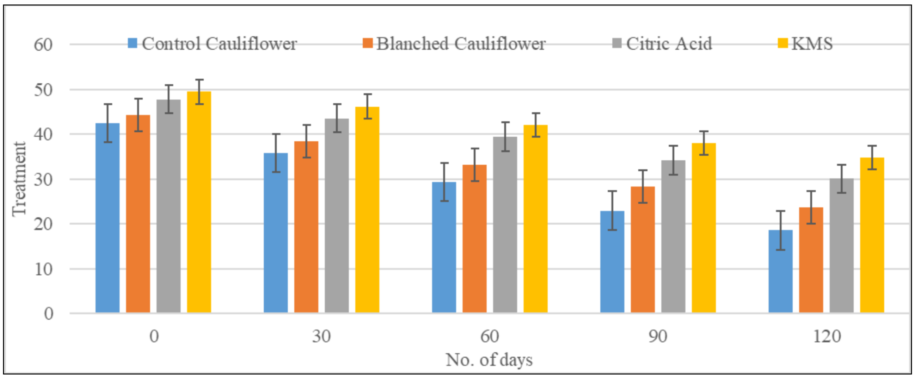

Fig 6: Effect of Storage on Ascorbic Acid Content of Cauliflower Under Different Treatments

Previous research by Sapers and Simmons (2001) [30] and Kumar *et al*. (2012) [15] also supports the role of chemical preservatives in enhancing the shelf life of nutrient-rich vegetable powders. In comparison, powders that were left untreated or only blanched showed significant nutrient losses, highlighting the importance of chemical treatments when long-term preservation is the goal. The present study further confirms that both potassium metabisulfite (KMS) and citric acid are effective in maintaining the nutritional quality of cauliflower during storage.

4. Conclusion

This study looked at how different pre-treatments Control (no treatment), Blanching, Citric Acid, and Potassium Metabisulfite (KMS) affect the storage quality of dehydrated cauliflower over 120 days at room temperature. The results showed that pre-treatments are very important for keeping nutritional value, slowing spoilage, and improving storage stability. The pH levels dropped in all samples during storage, with the untreated control showing the steepest decline, meaning it was more prone to microbial and enzymatic activity. KMS-treated cauliflower had the smallest drop in pH, thanks to its strong preservative effect, while citric acid samples also showed good stability by preventing microbial growth. Blanching caused moderate changes because it only partly inactivated enzymes. Moisture content increased in all samples, since dried powders naturally absorb water from the air. The control samples absorbed the most, going above 7% moisture, whereas KMS samples absorbed the least. Citric acid and blanching helped limit moisture gain to a moderate extent. Acidity went up in all treatments, with citric acid samples remaining the highest throughout because of the added acid. KMS slowed down the increase in acidity by preventing microbial activity, while the control and blanched samples had lower values but less protection overall. Browning also increased in every treatment. The control browned the fastest due to both enzymatic and non-enzymatic reactions.

Blanching slowed browning by disabling enzymes, while citric acid further reduced it with its antioxidant effect. KMS-treated samples showed the best color retention, proving its effectiveness against oxidation. Ash content decreased slightly in all treatments, with control samples holding the most minerals but performing poorly in other quality aspects. Vitamin C (ascorbic acid) dropped quickly in control and blanched samples, while citric acid and especially KMS treatments preserved much higher amounts. The KMS proved to be the most effective treatment for maintaining pH, controlling moisture uptake, slowing browning, and preserving vitamin C, making it suitable for commercial use. Citric acid also worked well and may be preferred for clean-label products. Blanching showed moderate benefits, while untreated cauliflower powder performed the worst. These results show that proper pre-treatments are essential for long-term storage of vegetable powders. Future work should focus on combining blanching with preservatives and using better packaging methods to further improve product quality and market value.

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