Tribhuvan University Journal of Food Science and Technology
Volume 3
DOI: 10.3126/tujfst.v3i3.94477

ORIGINAL RESEARCH PAPER

Effects of Pretreatment and Drying Conditions on Physical Properties and Bioactive Components of Garlic (*Alium sativum*) Powder

Navin Gautam*[1] and Manish Kafle[1]

[1]*Central Campus of Technology, Tribhuvan University, Dharan, Nepal*

Abstract

Garlic (Allium sativum) is rich in bioactive compounds but highly perishable. Drying is a key preservation method; however, inappropriate pretreatments and drying conditions often compromise its nutritional and functional quality. This study addresses the need to optimize these parameters to retain bioactive components while improving the physical properties of garlic powder for effective utilization as a functional food ingredient. The pretreatment of garlic cloves was carried out as follows: soaked in 0.2% potassium metabisulfite (KMS), citric acid (CA) solution, and distilled water (1:1w/v) for 10 min, followed by drying in a cabinet dryer at 45, 55, and 65℃, and ground using a coffee grinder and stored in aluminum-coated plastic bags. Bioactive components, viz., antioxidant activity, total polyphenol, flavonoid, ascorbic acid, and physical properties, viz., bulk density, true density, porosity, and water absorption capacity, solubility index were analyzed. Antioxidant activity and total polyphenol content was highest for KMS-treated garlic dried at 55℃. Flavonoid content was highest for citric acid treated garlic cloves dried at 45℃ and ascorbic acid was highest for KMS-treated and dried at 65℃. Physical properties of garlic powder found that drying at higher temperatures increased bulk density, true density, porosity, and water absorption capacity, but decreased solubility index. This study demonstrates that pretreatment and drying conditions significantly influence the physical properties and retention of bioactive components in garlic powder. Appropriate combinations of pretreatment and drying parameters can enhance physical properties while minimizing losses of bioactive components.

Keywords:
Garlic
Pretreatment
Temperature
Bioactive
Properties

Article history:
Received: 16 Nov 2024
Received in revised form: 13 Mar 2025
Accepted: 05 May 2025

*Corresponding author at:
E-mail address: nabin.gautam@cct.tu.edu.np
Contact no.: +9779842063758

Introduction

Garlic (*Allium sativum L.*) is a widely grown culinary spice that is consumed globally to increase flavor, ailment treatment, and protection against microbial invasion (Amunugoda et al., 2020; Sunanta et al., 2023). Studies have suggested health beneficial properties of garlic such as anti-inflammatory, antimicrobial, antioxidant, cardio protective, immunomodulatory, anticancer, detoxifying, and neuroprotective properties. These properties are attributed to the bioactive compounds present in garlic such as organosulfur compounds (alliin, allicin, allyl sulfide, diallyl disulfide), phenolic acids (caffeic, *p*-coumaric, and ferulic acids), and flavonoids (quercetin, kaempferol, and apigenin (Yan et al., 2021; Bazaraliyeva et al., 2022; Sunanta et al., 2023). According to Lidiková et al. (2022), the largest share of polyphenolic compounds in garlic is represented by phenolic acids and flavonoids. Phenolic acids are among the most important antioxidants that protect the human organism against the negative effects of free radicals. Garlic processing significantly alters the levels and bioavailability of its bioactive compounds (Sunanta et al., 2023). Thermal processing of garlic leads to partial degradation of native phenolics but simultaneously generates new antioxidant compounds, resulting in enhanced overall antioxidant capacity (Najman et al., 2020). On the other hand, thermal processing can produce Maillard reaction products by the condensation of sugars with free amino acids, peptides or proteins leading to the formation of a wide variety of brown melanoidins that act as antioxidants exhibiting chain breaker, oxygen scavenger and metal-chelating properties (Queiroz et al., 2014).

Pretreatments with potassium metabisulfite (KMS) and citric acid are commonly applied to reduce enzymatic browning and oxidative losses. Studies have shown that KMS pretreatment helps stabilize phenolic compounds by inhibiting polyphenol oxidase activity, thereby reducing enzymatic degradation during drying (Thakur et al., 2025). Similarly, citric acid acts as a chelating agent, binding to metal ions that catalyze oxidation, which helps in preserving phenolic content during thermal processing (Al-Dabbas et al., 2023). In studies involving similar horticultural products, a combination of KMS and citric acid has been shown to yield superior quality in cabinet-dried samples by maintaining higher levels of total phenolic content (TPC) and antioxidant capacity compared to untreated controls (Kumar & Sagar, 2014; Lučić et al., 2023). Despite these benefits, some loss remains inevitable during hot-air cabinet drying at temperatures such as 60°C, as prolonged thermal exposure can still lead to the leaching of soluble nutrients or the thermal decomposition of specific phenolic fractions (Pandiselvam et al., 2023; Zheng et al., 2023). Nevertheless, the application of 0.2% KMS or optimized citric acid solutions remains a standard industrial approach to maximize the retention of these health-promoting compounds in the final dehydrated product (Kumar & Sagar, 2014). Improper drying causes significant degradation of bioactive compounds and physical properties such as rehydration ratio, dehydration ratio, tapped density, and bulk density in garlic powder (Thakur et al., 2025). Pretreatments such as blanching, osmotic dehydration, and chemical dips can reduce enzymatic activity, limit oxidative degradation, and preserve color, texture, and bioactive compounds during drying (Silva et al., 2015). This work was conducted to find the effect of pretreatment 0.2% potassium metabisulfite (KMS), 0.2% citric acid (CA) solution, and distilled water (1:1w/v), followed by drying at 45, 55, and 65℃ sliced garlic cloves in a cabinet dryer, on the physical properties and retention of bioactive components of garlic powder.

Materials and Methods

Materials

The local variety of garlic, "patane," was purchased from the local market. All the necessary chemicals, instruments, and equipment for analytical purposes were sourced from the laboratory of the Central Campus of Technology, Dharan, Sunsari, Nepal. Main chemicals used were Na_2CO_3 (Qualigens, Assay 99-101%), Folin Ciocalteu phenol reagent (Sigma-Aldrich, Inc.), Aluminium Chloride (Ultra-Pure Lab Chem Industries LLP, Assay 98%), 2,2- Diphenyl-1-picrylhydrazyl (DPPH)- (Sigma Aldrich, Inc.), Gallic acid (Oxford, Assay 98%), Methanol Lab Grade (Fusion Biotech, Assay-99%), Sulfuric acid, (Qualigens, Assay 98%) were used.

Methods

Pretreatment and drying of garlic cloves

Garlic cloves were pretreated with 0.2% potassium metabisulfite (KMS), 0.2% citric acid (CA) solution, and distilled water (1:1 w/v), and subsequently dried at 40, 50, and 60℃ in a cabinet dryer. Approximately 250 g of fresh garlic bulbs were weighed for each pretreatment. Separate samples were used for each treatment to avoid cross-contamination. The garlic cloves were separated from the bulbs and manually peeled to remove the outer skin. Cloves were cut into small pieces of thickness of 3 mm to maintain consistent drying rates and prevent uneven moisture content in the final product. The pretreatment methods involved dipping for 10 min in 0.2% potassium metabisulfite (KMS) solution, followed by steeping in distilled water for 10 min, 0.2% citric acid solution, and distilled water (control sample) for 10 min. The pretreated and control garlic cloves were uniformly spread on trays and dried in a cabinet drier at temperatures of 45, 55, and 65℃ until their moisture level dropped to around 7%. The cabinet dryer's relative humidity ranged between 25±15%.

Preparation of garlic powder

All pretreated and control dried garlic cloves were ground using a coffee grinder for approximately 1-2 min, particle size was measured using a 60-mesh sieve, and garlic powder was packed in 85 GSM aluminum-coated plastic bags, sealed by heat, and stored at room temperature (27 ± 2℃) for analysis.

Determination of bulk and true density

The bulk density and true density were measured using the method outlined by Amunugoda et al. (2020) with slight modifications. 5 g of the sample was carefully poured into a dry 50 ml graduated measuring cylinder. The cylinder was then tapped gently 25 times. The volume occupied by the powder was noted, and the bulk density was calculated using the following formula and expressed as g/cm^3.

$$\text{Bulk density} = \frac{\text{Weight of powder}}{\text{Volume of powder}}$$

True density was calculated by filling approximately 2g of garlic powder in a measuring cylinder containing toluene. Then the rise in toluene level (mL) was measured, and true density was calculated:

$$\text{True density} = \frac{\text{Weight of powder (g)}}{\text{Rise in toluene level (ml)}}$$

Porosity

Porosity of the powder samples was determined using the method described by Sahin & Sumnu (2006). Porosity is an important physical property that characterizes the texture and quality of dry and intermediate-moisture foods. This is calculated using the relationship between the bulk and the true density of the powder as:

$$\text{Porosity} = 1 - \frac{\text{Bulk density}}{\text{True density}}$$

Water solubility index (WSI) and water absorption capacity (WAC)

Water solubility index and water absorption capacity of garlic powder were determined by the method described by Poojitha et al. (2020). Briefly, approximately 1 g of powder was taken in a centrifuge tube and mixed with 10 ml of distilled water, centrifuged for 10 min at 3,000 rpm. The supernatant was dried at 105°C to determine dry solid weight (for WSI), and the residue was weighed (for WAC).

$$\text{Water solubility index} = \frac{\text{Weight of dry solids in supernatant}}{\text{Weight of dry sample}} \times 100$$

$$\text{Water absorption capacity} = \frac{\text{weight of wet sediment}}{\text{weight of dry sample} - \text{weight of dry solids}}$$

Proximate composition of garlic

Proximate constituents include moisture content, crude fat, crude protein, total ash, crude fiber, and carbohydrate. Proximate composition of fresh and dried garlic powder was determined by the method described by Ranganna (1986).

Ascorbic acid content

Ascorbic acid was determined by the 2,6-dichlorophenol indophenols titration method described in AOAC (2005).

Extract preparation for the analysis of TPC, TFC and DPPH radical scavenging activity

The methanolic extraction method was used to extract the bioactive compounds described by Ereifej et al. (2016) with modification. 1 g of garlic powder under each pretreatment and drying condition was weighed out and mixed with 100 mL of 80% methanol to obtain an aqueous extract. Extraction was carried out under stirring for 60 min at 60℃. Each one was filtered using filter paper into a 100 mL volumetric flask, the volume was made up to the mark using the same extractant and kept in the dark at refrigerated temperature until the time of analysis. The filtrate was used for the analysis of TPC, TFC, and antioxidant activity.

Total phenolic content

The total phenolic content (TPC) of garlic powder was determined spectrophotometrically at 725 nm using the Folin-Ciocalteu method described by Ereifej et al., (2016). Briefly, 0.2 mL of extract was mixed with 0.4 ml of 10% Folin-Ciocalteu reagent in methanol, followed after 3 min by 0.8 ml of 10% sodium carbonate. After 1 h incubation at room temperature, absorbance was measured against a reagent blank. Results were expressed as gallic acid equivalents (mg GAE/g) on a dry weight basis; gallic acid was used to create a calibration curve. The standard curve was generated using the gallic acid standard as follows: 200 mg of gallic acid were dissolved in 20 ml of distilled water, the working standard used for preparing calibration curve (10- 400 mg/l) i.e. concentrations of 0, 10, 25, 50, 100, 200, and 400 ppm were prepared, all reagents were added as above, and the absorbance was measured at 765 nm.

Antioxidant activity

The DPPH radical scavenging assay was used to evaluate antioxidant activity, following the method described by Panico et al. (2009) with necessary modifications. Briefly, 0.1 mM DPPH solution was prepared by dissolving 3.94mg DPPH in 100 ml methanol. For the assay, 0.5 ml of each pretreated and dried conditions garlic powder extract was combined with 4 ml of DPPH solution and incubated in the dark for 30 min. The final concentration of the extract was adjusted to 1.11 mg/ml before analysis. Absorbance was measured at 517 nm using a UV–visible spectrophotometer. A control sample containing only DPPH solution (without extract) was prepared under identical conditions. The percentage of radical scavenging activity (%antioxidant activity) was calculated using the following equation:

$$\%\text{Radical scavenging activity} = \frac{A_{Control} - A_{Sample}}{A_{Control}} \times 100$$

Where $A_{Control}$ is the absorbance of the control (DPPH solution without extract) and A_{Sample} is the absorbance of the test sample (DPPH solution with extract).

Flavonoid content

The flavonoid content was determined using the aluminum chloride assay method described by Zhishen et al. (1999). In this method, 2 ml of the solution was pipetted into a test tube, and 0.2 ml of 5% sodium nitrite ($NaNO_2$) was added, allowing it to stand for 5 minutes. Subsequently, 0.2 ml of aluminum chloride ($AlCl_3$) was pipetted into the tube, and the mixture was allowed to stand for an additional 5 min. Next, 2 ml of 1 N Sodium Hydroxide (NaOH) was added to the tube, and the volume was adjusted to 5 ml. After 15 min, the absorbance was measured at 510 nm against a reagent blank. The results obtained are then calculated from the standard curve of quercetin (20, 40, 60, 80, 100 µg/ml). The flavonoid content was expressed as quercetin equivalents per g dry extract (QE/g dry extract).

Statistical analysis

The triplicate data from each experiment analysis were subjected to one-way analysis of variance (ANOVA) using IBM SPSS Statistics version 27. Means were compared by the Tukey's HSD test at 5% level of significance to determine whether the samples were significantly different from each other and to identify which one is superior. MS Excel 2013 was employed for general calculations, graphing, and diagram construction. All results are presented as mean ± standard deviation.

Results and Discussion

Proximate and chemical composition of fresh garlic

The proximate and composition of bioactive components of fresh garlic shown in Table 1 and Table 2, respectively.

The values of proximate constituents of fresh garlic measured on a wet weight basis were found to be similar to those reported by Mutasim & Elgasim (2016). Variation in the proximate composition of garlic may be attributed to variety and geographical region.

The values for all parameters were found consistent with several studies (Gorinstein et al., 2005; Herdyastuti et al., 2021; Khalid et al., 2014). Gorinstein et al. (2005) reported that the DPPH radical scavenging activity of fresh garlic 68.9% and the total polyphenol content was 42.2-52.4 mgGAE/100g fresh weight. The result of the vitamin C content was lower than the result obtained by Herdyastuti et al. (2021). Khalid et al. (2014) reported that the flavonoid content in garlic is 35 mg QE/g of garlic db.

Table 1
Proximate analysis of fresh garlic on a wet basis per 100 g

Parameter	*Value (%)*
Moisture content	65.92±0.23
Ash	1.48±0.15
Protein	14.62±0.11
Fat	1.09±0.16
Crude fibers	0.85±0.13
Carbohydrates	16.03±0.33

Note. Values are the mean of three determinations ± standard deviation.

Table 2
Composition of bioactive components in fresh garlic

Parameters	*Value*
% Antioxidant acitivity	72.8±1.96
Total polyphenol content (mgGAE/g db)	27.24±0.36
Flavonoid (mg QE/g db)	22.13±0.57
Vitamin C (mg/100g db)	45.65±0.5

Note. Values are the mean of three determinations ± standard deviation.

Effect of pretreatment and drying temperatures on physical properties of garlic powder

The physical properties of dried garlic powder are summarized in Table 3. Bulk density and true density values were used to calculate porosity, while solubility and swelling capacity reflected the powder's functional characteristics in aqueous systems.

The garlic powder obtained after pretreatment with KMS and dried in a cabinet dryer at 65°C had the highest bulk density and the lowest value was observed in distilled water pretreated and dried in a cabinet drier at 45°C as shown in Table 3. Significant difference ($p<0.05$) in bulk density of powder pretreated with KMS against other treated powder. A similar study was conducted by Masoumi et al. (2006), who reported the bulk density of fresh garlic was 0.462. The data indicated that higher temperatures correspond to an increase in bulk density. Lower bulk density causes lower particle homogeneity, and by minimizing interparticle voids, the surrounding surface area decreases (Sarker et al., 2021). The garlic powder that has treated with KMS and dried in a cabinet dryer at 65°C had the highest true density and the lowest value was observed in distilled water treated and dried in cabinet drier at 45°C shown in Table 3. A similar study was conducted by Lilia et al. (2017), where the true density of dried garlic at 50°C was found to be 1.441. The data presented in Table 3 indicate that there is a positive correlation between temperature and true density, with little more in citric acid and KMS pretreated samples. There was no significant difference ($p>0.05$) of garlic powder obtained after pretreatment with KMS, citric acid and distilled water and dried at different temperatures. Our finding was similar to the result reported by Lilia et al. (2017). Increased porosity among powders results in increased occluded air, which oxidizes the particles and decreases storage stability. Pretreated and control garlic powder obtained after drying at different temperatures were not significantly different ($p>0.05$) in terms of solubility index (SI) and water absorption capacity (WAC). The highest SI was found in control garlic samples than pretreated garlic powder. The decrease in SI could be attributed to the degradation of pectin substances during processing and structural modifications that occur when water is removed. Our finding are closely aligned with the result obtained by Poojitha et al. (2020). Also, a similar result was obtained in ginger by Sarker et al. (2021). The highest WAC was found in KMS pretreated garlic powder and dried at 45 and 55°C. Data presented in Table 3 indicates that there is a direct relation between temperature and swelling capacity, where higher temperatures result in increased swelling. A similar study was conducted by Adebowale & Adeyanju (2023), where the WAC of garlic powder was found to be 8.86-6.47.

Effect of pretreatment and drying temperature on bioactive component of garlic powder

DPPH antioxidant activity of garlic powder ranged from 51.2-65.743%. The KMS pretreated garlic powder dried at 55°C had the highest antioxidant activity i.e., 65.743% followed by citric acid pretreated 65.093% and dipped in distilled water 61.15%. No significance difference ($p>0.05$) of CA and KMS pretreated garlic cloves dried at 45, 55 and 65°C in a cabinet dryer in terms of % antioxidant activity. Widyaningsih et al. (2021) found higher antioxidant activity of black garlic extract powder obtained after drying for 30 h at temperature of 60°C. The antioxidant activity of garlic powder was found to increase drying at a temperature range 45°C-55°C shown in Figure 1. Our result was similar to finding made by Alide et al. (2020). Chumroenphat et al. (2021) concluded that variations in drying conditions would cause different responses in the deterioration of antioxidant activity for turmeric and found higher DPPH antioxidant activity on hot air dried compared to other drying methods.

The effect of pretreatments and drying temperature on TPC of dried garlic powder is shown in Figure 2. No significance difference ($p>0.05$) of KMS and CA pretreated garlic cloves dried at 45 and 55 and 65°C in a cabinet dryer in terms of TPC, but significantly different than pretreated in distilled water at all drying temperatures.

Table 3
Bulk density, true density, porosity, solubility and Swelling capacity of garlic powder

Methods of drying	*Treatments*	*Bulk density (g/ml)*	*True density (g/ml)*	*Porosity*	*Solubility index %*	*Water absorption capacity (g/g)*
	Control	0.49±0.02[a]	1.24±0.03[a]	0.60±0.17[a]	17.51±0.04[a]	6.04±0.09[a]
Cabinet dryer (45℃)	Citric Acid	0.51±0.05[a]	1.33±0.03[b]	0.61±0.13[a]	15.88±0.05[b]	6.59±0.08[b]
	KMS	0.57±0.04[b]	1.47±0.05[c]	0.60±0.01[a]	14.08±0.09[c]	7.26±0.001[c]
	Control	0.51±0.04[a]	1.25±0.03[a]	0.59±0.02[a]	17.87±0.05[a]	6.03±0.02[a]
Cabinet dryer (55℃)	Citric Acid	0.52±0.05[a]	1.36±0.02[b]	0.61±0.04[a]	15.97±0.06[b]	6.61±0.08[b]
	KMS	0.59±0.01[c]	1.53±0.02[c]	0.612±0.01[a]	14.34±0.04[c]	7.26±0.01[c]
	Control	0.51±0.03[a]	1.25±0.02[a]	0.59±0.03[a]	16.21±0.03[a]	6.03±0.12[a]
Cabinet dryer (65℃)	Citric Acid	0.52±0.02[a]	1.35±0.02[b]	0.61±0.08[a]	15.58±0.05[b]	6.613±0.01[b]
	KMS	0.60±0.04[c]	1.54±0.03[c]	0.60±0.02[a]	15.39±0.03[c]	7.196±0.02[c]

Note. The data presented are the mean values ± standard deviation obtained from triplicate measurements. Means sharing similar superscript are not significantly different at 5% significance level.

TPC ranged from 20.31- 20.72 mg GAE/g db. Maximum phenolic content found in KMS pretreated garlic powder and dried at 55℃, treated with KMS followed by citric acid pretreated (20.433 mg GAE/g) powder at the same temperature. Drying garlic cloves at 55℃, retained about 76.1% of the fresh total polyphenol content, indicating a substantial but not severe reduction (~24%). The loss likely reflects heat-driven degradation, oxidation, or leaching of phenolics and associated antioxidants during drying (Thakur et al., 2025). Lowest TPC was found in control sample dried at 45°C (15.41mg GAE/g). These results are consistent with Al-Dabbas et al. (2023).

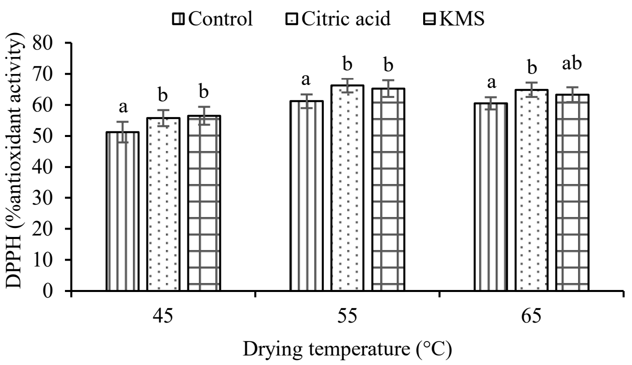

Figure 1
Effect of pretreatments and drying temperature on the Antioxidant Activity of dried garlic powder. Values with different letters are significantly different (p<0.05) within each temperature group.

According to Herdyastuti et al. (2021), TPC of methanol extract of garlic powder ranged from 14.658-21.09 mg GAE/g. The higher phenolic content in KMS and citric acid pretreated samples can be attributed to their antioxidant and anti-enzymatic roles in minimizing oxidative degradation of phenolics during drying (Kalt, 2005; Sivakumar et al., 2010). Similarly, Sharma & Prasad (2001) noted that the sulfur compounds in garlic can be preserved more effectively through chemical pretreatments and moderate drying conditions. KMS inhibits polyphenol oxidase (PPO) activity, thus reducing the enzymatic oxidation of phenolic compounds during drying. Citric acid also acts as a chelating agent, maintaining phenolic stability by reducing oxidative stress during thermal processing (Tomás-Barberán & Espín, 2001).

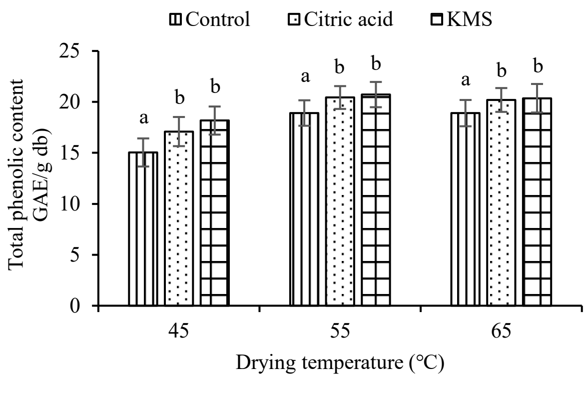

Figure 2
Effect of pretreatments and drying temperature on TPC of dried garlic powder. Values with different letters are significantly different (p<0.05) within each temperature group.

Moderate temperatures have been found optimal for garlic, promoting enzyme inactivation while limiting oxidative losses, as suggested by Sagar et al. (2022). Since many phenolics are concentrated in or near the skin, careful peeling during sample preparation is essential to minimize phenolic loss (Tomás-Barberán & Espín, 2001; Kalt, 2005). Figure 3 illustrates the flavonoid content of garlic powder dried in a cabinet dryer at different temperatures. No significance difference (p>0.05) of

KMS and CA pretreated garlic cloves dried at 45 and 55°C in a cabinet dryer in terms of flavonoid content, but significant difference observed at 65°C. Flavonoid content of garlic powder ranged from 15.65-20.13 mg QE/g among the different samples. Garlic cloves pretreated with citric acid and dried at 45°C showed the highest flavonoid content; this may be due to acid-induced cell wall breakdown and enhanced release of phenolic compounds. Drying garlic cloves at 45°C retained about 90% of the flavonoid content compared to fresh garlic, with only a modest reduction of about 10%. This indicates that low-temperature drying preserves flavonoids effectively compared to higher drying temperatures. Our result closely aligned with the findings made by Jang et al. (2018). Sulfite pretreatment (e.g., KMS) can partially break down phenolic and flavonoid compounds, resulting in decreased flavonoid content (Al-Dabbas et al., 2023). Flavonoids are heat-sensitive and degrade during hot air drying; higher temperatures lead to reduction in their content compared to fresh garlic (Chaaban et al., 2017).

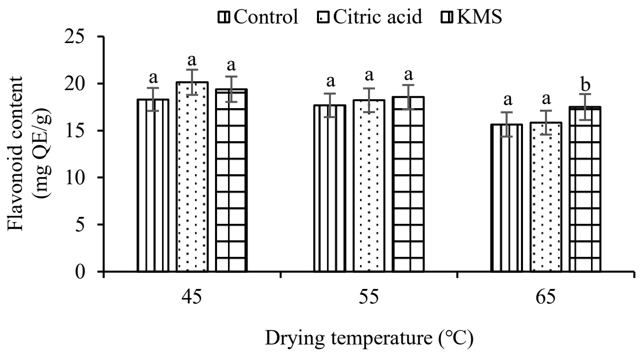

Figure 3
Effect of pretreatments and drying methods on TFC of dried garlic powder. Values with different letters are significantly different (p<0.05) within each temperature group.

Ascorbic acid of garlic powder dried in a cabinet dryer at different temperatures was found in the range 16.15-25.67 mg/100g db. The highest ascorbic acid retention was found in garlic powder pretreated with KMS and cabinet dried at 65°C, which is shown in Figure 4. No significance difference (p>0.05) of CA and KMS pretreated garlic cloves dried at 45 and 55 and 65°C in a cabinet dryer in terms of ascorbic acid. Drying garlic cloves at 65°C retained only 56.2% of the original ascorbic acid content, indicating a substantial loss of about 44% compared to fresh garlic. At lower drying temperatures (45–55°C), garlic cloves require longer drying times, which prolongs exposure to oxygen and allows enzymes such as ascorbate oxidase to remain active, thereby accelerating oxidative degradation of vitamin C (Lee & Kader, 2000). These results indicate that cabinet drying at higher temperatures can retain ascorbic acid; no significant difference was detected between samples dried at 55 and 65°C. Our findings were similar to the results obtained by Herdyastuti et al. (2021). According to Qiu et al. (2020), raised temperatures can increase water-soluble vitamins like vitamin C, but decrease fat-soluble vitamin levels. As the temperature rises above 70°C ascorbic acid content decreases and becomes unstable (Nogata et al., 2006; Herdyastuti et al., 2021).

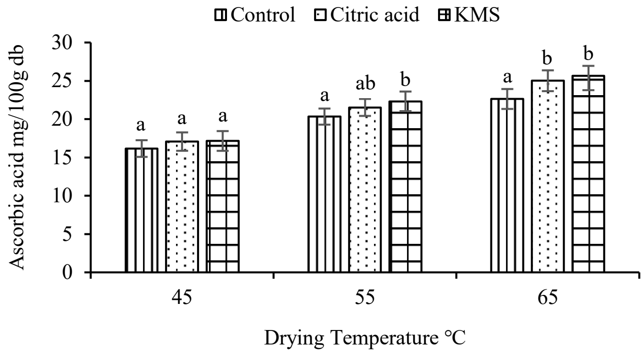

Figure 4
Effect of pretreatments and drying methods on Ascorbic acid of dried garlic powder. Values with different letters are significantly different (p<0.05) within each temperature group.

In contrast, drying at 65°C shortens the dehydration period, rapidly reduces water activity, and inactivates degradative enzymes, leading to greater preservation of ascorbic acid despite the higher thermal load (Giannakourou & Taoukis, 2021). Pretreatments with citric acid and potassium metabisulfite further enhance stability by lowering pH and scavenging reactive oxygen species, which are particularly effective when drying occurs rapidly (Sharma & Prasad, 2006).

Conclusions

This study demonstrated that pretreatment and drying temperature significantly affect the physical and bioactive properties of garlic powder from *Allium sativum*. Garlic cloves pretreated with potassium metabisulfite and dried at 55°C exhibited the greatest retention of antioxidant activity and total polyphenols, whereas citric acid pretreatment followed by drying at 45°C was effective in preserving flavonoids. Garlic cloves pretreated in KMS solution and dried at 65°C accelerates moisture removal, lowers water activity more quickly, and deactivates degradative enzymes, thereby ensuring greater retention of ascorbic acid despite the higher thermal stress. While higher drying temperatures boosted bulk density and water absorption, they lowered solubility and led to substantial vitamin C losses. These findings provide guidance for small and medium-scale processors to standardize drying protocols that minimize nutrient loss while improving powder stability, density, and water absorption capacity.

Acknowledgements

Special thanks to campus laboratory staff and students who helped to complete this work.

Conflict of Interest

The authors declare no conflict of interest.

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