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Fresh crushed garlic exhibits superior allicin and pyruvic acid stability, while fresh sliced garlic leads in phenolic and antioxidant content

Taha Rababah [a,*], Muhammad Al-U'datt [a], Malak Angor [b], Ahmad Alsaad [c], Yazan Akkam [d], Sana Gammoh [a], Ghazi Maghableh [e], Tamara Smadi [a], Ali Almajwal [f], Sevil Yücel [g], Bandar N. Hamadneh [h], Vaida Bartkutė-Norkūnienė [i], Muhammad Azam [j], Numan AL-Rayyan [k,l,*]

[a] Department of Nutrition and Food Technology, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan
[b] Nutrition and Food Technology, Al-Balqa Applied University, Jordan
[c] Department of Physics, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan
[d] Faculty of Pharmacy, Yarmouk University, Jordan
[e] Industrial Engineering department -Yarmouk University, Irbid-Jordan, Yarmouk University, Irbid-Jordan. P.O. Box 21163, Jordan
[f] Department of Community Health Sciences, College of Applied Medical Sciences, King Saud University, P.O. Box 10219 Riyadh 11433, Saudi Arabia
[g] Yildiz Technical University, Istanbul Turkey
[h] King Abdullah University Hospital, University of Science and Technology, Irbid, 22110, Jordan
[i] Utena Higher Education Institution, Maironio Str. 7, Utena, Lithuania
[j] National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan
[k] School of Medicine and Public Health, University of Wisconsin-Madison, United States
[l] National Agricultural Research Center, Jordan

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ABSTRACT

This study investigates the stability of allicin, phenols, and antioxidants in different forms of garlic (fresh whole peeled, fresh sliced, fresh crushed, and dried slices) under various storage conditions (0 to 2 days at 4 ºC and 20 ºC). The garlic contents of allicin and pyruvic acid, total phenols, and antioxidant activity were determined. Sensory evaluation of hummus samples, enriched with garlic in varying treatments, was conducted by 40 participants to assess acceptability and intensity of flavor, aroma, and pungency. Fresh garlic exhibited allicin levels ranging from 0.6 to 32.14 mg/g, while dried garlic showed significantly lower levels (3.77 to 6.68 mg/g). Maximum allicin stability in fresh garlic was observed after 10 min at 20 ºC, with pyruvic acid peaking after 10 min at 4 ºC. Freshly sliced and crushed garlic retained the highest phenol content and antioxidant activity immediately after preparation, whereas dried garlic had reduced levels due to thermal processing. Consumer testing revealed that hummus with fresh crushed garlic at 10 min and 20 ºC was preferred, while dried garlic at 20 min and 4 ºC had the strongest flavor and aroma. In conclusion, fresh crushed garlic is optimal for allicin and pyruvic acid content, while fresh sliced garlic excels in phenol and antioxidant levels; drying notably diminishes these beneficial compounds, affecting flavor and consumer preference. According to these results, consuming the fresh garlic after 10 min of mashing it at room temperature is recommended for optimal allicin yield and pungency.

1. Introduction

Garlic, (*Allium sativum)*, is one of the ancient crops, and it has been named the "aroma" vegetable since it has been used as a flavoring in cuisine and as a medication due to its numerous health and wellness advantages in many civilizations (Botas *et al.*, 2019; Netzel, 2020). Garlic has a high concentration of functionally active compounds and a diverse chemical composition (Marchese *et al.*, 2016). Multiple research studies have demonstrated that the health benefits attributed to fresh garlic extract are believed to be associated with the presence of a total of 33 sulfur compounds (Amagase, 2006; Bhandari, 2012; Kovarovič *et al.*, 2019). Those benefits include antioxidant properties, anti-inflammatory activity, antimicrobial activity, immunological activation, cardiovascular defense, antitumor, anti-carcinogenic, gastric safety, anti-diabetic function, anti-obesity activity, the nervous and endocrine systems (Shang *et al.*, 2019; Gam *et al.*, 2021).

Garlic has a weak, undetectable odor until it is peeled. When peeled, sliced, or crushed, it forms a compound called allicin, which releases a strong odor containing sulfur glycosides (Yusuf *et al.*, 2018). Allicin, or diallyl thiosulfinates, is the most active biological ingredient in garlic

* Corresponding authors.
E-mail addresses: trababah@just.edu.jo (T. Rababah), alrayyan@wisc.edu (N. AL-Rayyan).

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(Farías-Campomanes *et al.*, 2014), accounting for over 70 % of the total thiosulfinates found in cloves (means one individual lobe within a head of garlic) (M.S. Rahman, 2007), it is highly unstable and can break-down even at ambient temperature (Ilić *et al.*, 2015; Zhu & Zeng, 2020), in a matter of days or hours to far more stable sulfur-containing compounds (Rybak *et al.*, 2004). In addition, allicin is not present in garlic before crushing; it is synthesized from alliin (S-Allyl-L cysteine-sulfoxides) by the enzyme alliinase (Abe *et al.*, 2020). Upon processing or consumption, these compounds contribute to the distinct pungent aroma of garlic (Kovarovič *et al.*, 2019).

Khar et al. (2011) studied 93 garlic ecotypes for allicin content and observed variability in allicin content in each one. Prati et al. (2014) studied allicin content in 5 cultivars for three forms of processed garlic (unsalted garlic paste, chopped fried garlic, and fried sliced garlic) for a long period of storage reaching 180 days, with the most loss of allicin recorded in fried garlic, followed by paste. Another researcher reported that cooking methods at home (boiling, microwaving, pressure cooking, griddling, frying, and baking) have been demonstrated to affect the important components and antioxidant activity of garlic (Martins et al., 2016). The stability of allicin, which is typically thought of as unstable, has been the subject of several research. The stability of allicin varies depending on environmental parameters including temperature and the solvent used to dissolve it (Chan *et al.*, 2012). This unstable chemical has poor solubility in water (Marchese *et al.*, 2016). The most prevalent bioactive components of garlic are naturally sensitive to temperature degradation, which reduces their effectiveness (Martins *et al.*, 2016). The high volatility and instability of allicin limit the use of garlic as a pharmacologically active drug, which significantly restricts its commercial usage. Also, allicin's instability is one issue that inhibits its chemical uses (Ilić *et al.*, 2011).

Given the significant volatility of organosulfur compounds in garlic, such as allicin, proper storage conditions are critical for retaining the excellent quality of garlic bulbs and by-products. The period of storage is critical for garlic's bioactive qualities (Martins et al., 2016). Also, storage temperature is particularly significant since it can influence the chemical structure and, as a result, the ultimate bioactivity intensity of garlic and allicin content over time (Veríssimo et al., 2010). From another point of view, for processed foods, the approach has a substantial impact on the retention of bioactive chemicals from garlic, especially those connected to antioxidant properties like the one achieved by allicin from garlic (Prati et al., 2014). On the other hand, some active components in garlic under long period storage. S-allyl-L-cysteine is one of the main components in garlic. It is an organic substance that dissolves in water. Both during extraction in an aqueous media and with prolonged storage, its concentration tends to rise (Santhosha *et al.*, 2013). This confirmed with a study done by Fei et al. (2015), Garlic cloves' antioxidant capacity topped after 8 weeks of storage at 20 ˚C, while the highest levels of organosulfur compounds and polyphenols were found between 6 and 8 weeks of storage, after which there was a notable decline.

The previous work available in the literature relates to the evaluation of allicin stability in different solvent extractions, showing allicin stability in polar and nonpolar solvents after extraction (Zalepugin et al., 2015). In our study, we evaluated allicin stability before the extraction process in different forms (freshly sliced, freshly crushed, and dried slices) during short storage intervals, which were considered practical for daily use. Based on the above, this study aims to evaluate the stability of allicin in fresh sliced garlic, freshly crushed garlic, and dried garlic slices under different storage conditions of time and temperature (from zero time to two days at 4 ºC and 20 ºC).

2. Materials and methods

2.1. Materials

Fresh white garlic (*Allium sativum* L.) bulbs and hummus (a dip made from pureed chickpeas, sesame seed paste and lemon) were purchased from the local market in Irbid, Jordan. Chickpeas and garlic are grown in the Jordan Valley area. Allicin standard (purity 98 %) was purchased from (TargetMol, EU). All chemical reagents utilized in this study were purchased from Sigma-Aldrich (St. Louis, MO, USA) or Fisher Scientific (Pittsburgh, PA, USA).

2.2. Sample preparation

This study analyzed three different forms of garlic: freshly sliced, freshly crushed, and dried garlic slices. Fresh whole garlic was used as a control. Thirteen samples were prepared from each forms of garlic, each weighing 10 g, and stored under different conditions of tempreture and time as follow: Zero time, 10 min at (4ºC, 20 ºC), 20 min at (4ºC, 20 ºC), 30 min at (4ºC, 20 ºC), 1 hour at (4ºC, 20 ºC), 1 day at (4ºC, 20 ºC) and 2 day at (4ºC, 20 ºC). Fresh garlic was cut into uniform slices (3.5 mm) using a kitchen knife (Fresh sliced), crushed into a paste using a garlic press (Fresh crushed), and dried slices were dried in the oven at 60 ºC for 24 h (Dried garlic). The garlic samples were prepared, labeled, and stored at different temperatures for different times as described in Table 1. The difference between the controls in the tables is due to the difference in the two experiments, as the table 2 compares the amount of allicin content in fresh sliced garlic and fresh crushed garlic, while the second table compares the amount of allicin content in fresh sliced garlic and dried garlic slices, as there is no reason to unify the controls for the two experiments. Most previous studies have studied changes in garlic components and their effectiveness over a long period, while our study studied changes in garlic components and their effectiveness over a short time to see if they are affected or not. Because these short periods may not be important to some, but they occur with most people during the use and preparation of garlic.

2.3. Garlic extraction

Garlic was extracted according to the method described by Bat-Chen et al. (2010) with some appropriate modifications. The modifications are as follows: the residue (Garlic extract residue left after evaporation process) was reconstituted with 5 ml of the mobile phase (50 % Water: 50 % Methanol) and homogenized by placing it in a closed beaker, then sonicated before filtration by filter paper.

Table 1
Storage condition (time and temperature) used in the experiment for fresh sliced garlic, fresh crushed garlic, and dried garlic slices.

Treatments	Temperature (ºC)	Time
Trt 1	20	0
Trt 2	4	10 min
Trt 3	20	10 min
Trt 4	4	20 min
Trt 5	20	20 min
Trt 6	4	30 min
Trt 7	20	30 min
Trt 8	4	1 h
Trt 9	20	1 h
Trt 10	4	1 day
Trt 11	20	1 day
Trt 12	4	2 day
Trt 13	20	2 day

Table 2
Allicin content (mg/g) in fresh sliced and fresh crushed garlic at different storage conditions (time and temperature).

Treatments**	Allicin content in fresh sliced garlic (mg/g) $	Allicin content in fresh crushed garlic (mg/g) $
Control	3.05 ± 0.03^{n}	3.05 ± 0.03^{l}
Trt 1	$3.53 \pm 0.02^{lB*}$	3.99 ± 0.07^{kA}
Trt 2	8.42 ± 0.03^{jB}	18.63 ± 0.03^{dA}
Trt 3	17.51 ± 0.02^{aB}	32.14 ± 0.02^{aA}
Trt 4	17.12 ± 0.03^{bB}	28.77 ± 0.02^{bA}
Trt 5	17.05 ± 0.13^{cB}	20.82 ± 0.01^{cA}
Trt 6	16.79 ± 0.02^{dB}	18.28 ± 0.02^{eA}
Trt 7	16.23 ± 0.01^{eA}	15.47 ± 0.03^{fB}
Trt 8	16.09 ± 0.02^{fA}	13.09 ± 0.02^{gB}
Trt 9	15.29 ± 0.02^{gA}	9.50 ± 0.02^{hB}
Trt 10	10.53 ± 0.03^{hA}	7.88 ± 0.03^{iB}
Trt 11	8.89 ± 0.02^{iA}	4.80 ± 0.02^{jB}
Trt 12	5.78 ± 0.02^{kA}	1.08 ± 0.01^{mB}
Trt 13	3.39 ± 0.02^{mA}	0.60 ± 0.02^{nB}

$ All values are means of three replicates and calculated on a wet basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

2.4. Identification of allicin in garlic extract by HPLC

Allicin stock solutions were prepared with 50 mg of allicin (Commercially available) dissolved in 5 ml of 60:40 (mixtures of water and methanol) as described by Rybak et al. (2004). The identification of the allicin peak was at 220 nm wavelength. Two vials (20 µL) were injected in the HPLC to determine the allicin content in the samples. The first vial was garlic extract without the standard, and the second was with the standard. Then, the intensity of the peak was compared to the standard to detect the wavelength of allicin in garlic extract.

2.5. Determination of allicin content in garlic extract by HPLC

The identification and quantification of allicin were performed in a high-performance liquid chromatography (HPLC) system (SHIMADZU, Japan). The determination of allicin in the garlic samples was performed according to the procedure described by de Diego et al. (2007). All analyses of each sample were performed at room temperature under isocratic conditions. The separation was carried out using the RP-18e column. The mobile phase consisted of methanol –water (50:50 v/v). The UV detection was made at 220 nm with some modifications in column dimensions (100 mm x 3 mm).

2.6. Determination of pyruvic acid content in garlic

The pyruvic acid content in garlic extract was measured according to a procedure described by Anthon and Barrett (2003). In a test tube, 1 millilitre of water was mixed with 25 millilitres of the cleared garlic filtrate. 1 ml of 0.25 g/l DNPH in 1 M HCl was added to this, and the samples were then put in a water bath set at 37 ˚C. One millilitre of 1.5 M NaOH was added after the samples had been out of the water bath for ten minutes. Next, the absorbance at 515 nm was measured. In place of the garlic sample, 25 µl of sodium pyruvate solutions with concentrations ranging from 0 to 8 mM were added to create a blank and standards.

2.7. Determination of total phenol content

The total phenol content of the garlic extract was determined using the Folin–Ciocalteu method, as previously described by Alu'datt et al. (2010). Gallic acid was used as a stock solution (50 mg/50 ml) to create a standard calibration curve. For every extract, the spectrophotometric analysis was conducted three times. Distilled water was used to dilute the phenolic compound-containing extract (10 ml extract diluted to 50 ml total). Next, 7.5 millilitres of One millilitre of the aforementioned solution was mixed thoroughly in a test tube with distilled water, then 0.5 millilitres of Folin-Ciocalteu reagent. One millilitre of 5 % sodium carbonate (Na2CO3) was added after four minutes. After mixing the ingredients, the green color's intensity was measured at 725 nm one hour later.

2.8. Determination of antioxidant activity

Anti-oxidant activity of the garlic extract was determined using a method described by Brand-Williams et al. (1995). The antioxidant activities were determined using DPPH as a free radical. Antioxidant solution in methanol 0.1 mL was added to 3.9 mL of methanol DPPH solution. The absorbance was determined at 515 nm.

2.9. Sensory evaluation

The scientific research committee reviewed and approved the study at the Department of Nutrition and Food Technology, Jordan University of Science and Technology to perform the sensory evaluation. The samples are hummus prepared according to the method conducted by Olaimat et al. (2017) then add to hummus different treatments of garlic as follow: hummus without garlic, hummus with fresh sliced garlic at Zero time, hummus with fresh sliced garlic after 10 min at 4 ºC, hummus with fresh sliced garlic after 10 min at 20 ºC, hummus with fresh sliced garlic after 20 min at 4 ºC, hummus with fresh crushed garlic after zero time, hummus with fresh crushed garlic 10 min at 4 ºC, hummus with fresh crushed garlic 10 min at 20 ºC, hummus with fresh crushed garlic 20 min at 4 º, hummus with dried garlic after zero time, hummus with dried garlic after 10 min at 4 ºC, hummus with dried garlic after 10 min at 20 ºC, and hummus with dried garlic after 20 min at 4 º. A sensory evaluation of hummus samples was conducted using a hedonic scale of acceptance (Yilmaz & Aydeniz, 2012), and Just About Right (JAR) scales to assess whether the intensity of an attribute is appropriate (Lawless & Heymann, 2010). A total of 40 participants from Jordan University of Science and Technology students, aged between 18 and 30 years, participated in this study. Different samples of hummus were prepared and garlic from different treatments was added to the hummus samples. Participants were directed to taste samples and evaluate them at individual tables, each participant was provided with thirteen plates. To eliminate carry-over factors, participants were also provided with green apples and water for mouth cleaning between samples. The participants were asked to record their acceptability scores (Hedonic scale) of samples for overall appearance, overall color, overall aroma, overall pungency, and overall flavor (9-point scale with 9 = extremely like and 1 = extremely dislike). Acceptability intensity scores (Just About Right (JAR) scales) of samples for flavor, aroma, and pungency (5-point scale with 5 = normal and 1 = too much).

2.10. Statistical analysis

The data were expressed as the mean ± standard deviation (SD). All the experiments and analyses were performed in duplicate. The data were analyzed using the procedure of the general linear model (GLM) using the JMP statistical package (JMP Institute Inc., Cary, NC, USA). The means were separated via a least significant difference analysis (LSD) of $p \leq 0.05$ values.

3. Results and discussion

3.1. Identification of allicin in garlic extract by HPLC

The main peaks in the chromatograms of garlic extract (GE) without standard and GE with standard are shown in Fig. 1 and Fig. 2. The peak that increased with the increase in the amount of allicin (standard) is the peak that expresses allicin, which was observed at retention time between 6 and 7 min (approximately 6.5 min).

3.2. Determination of allicin content in garlic extract by HPLC

Tables 2 and 3 demonstrate the mean of allicin content in fresh (sliced and crushed) (the difference between tables) and dried garlic slices with the effect of different storage conditions (time and temperature), also, Fig. 3. The allicin contents were significantly varied ($p < 0.05$) among treatments and forms. The highest allicin content between all treatments is (32.14 mg/g) and was found in fresh crushed garlic in Trt 3 (20 ºC, 10 min), whereas, the lowest allicin content (0.6 mg/g) was also found in fresh crushed garlic in Trt 13 (20 ºC, 2 days). According to several studies, there is significant variability in the garlic content of organic sulfur profiles between previous studies and our study due to two factors. The first cause was the use of different extraction solvents, which affects the degradation of allicin into other compounds such as dichloromethane. The second is an analysis of the many garlic genotypes utilized in the tests (Martins et al., 2016; Liu et al., 2020). A study done by M.S. Rahman (2007) called Raw garlic does not contain allicin, but CS-lyase (allinase) quickly produces it from alliin.

Table 2 shows that the amount of allicin in fresh (sliced and crushed) garlic in Trt 1 (20 ºC, time 0) is low because the enzymatic reaction that converts alliin to allicin takes about 10 min from the moment it is cut. There are a few reports of allicin nature called one of the active ingredients, allicin, is transformed over an extended period into

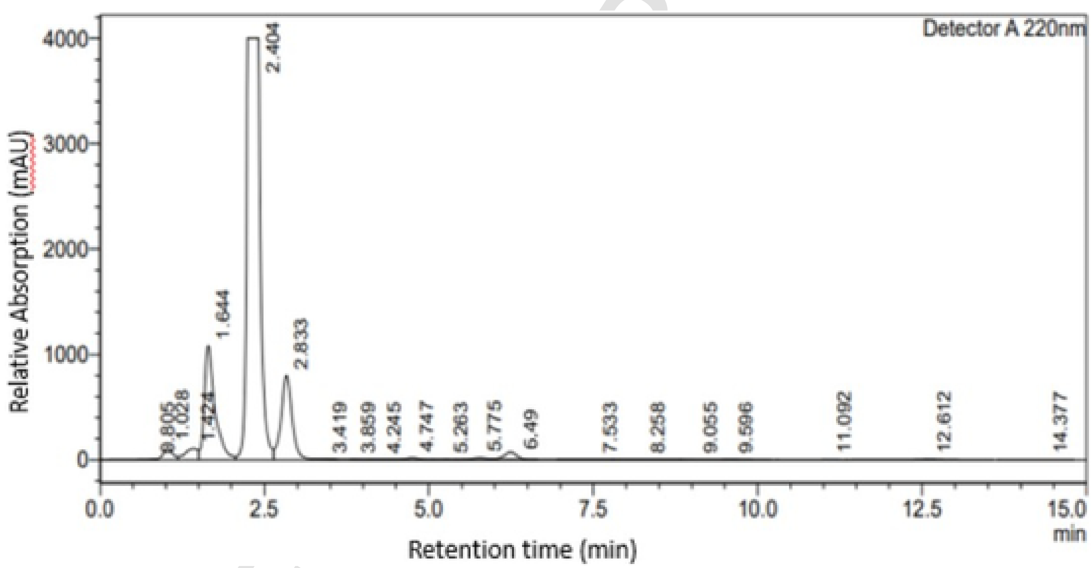

Fig. 1. Chromatogram of garlic extract without allicin standard.

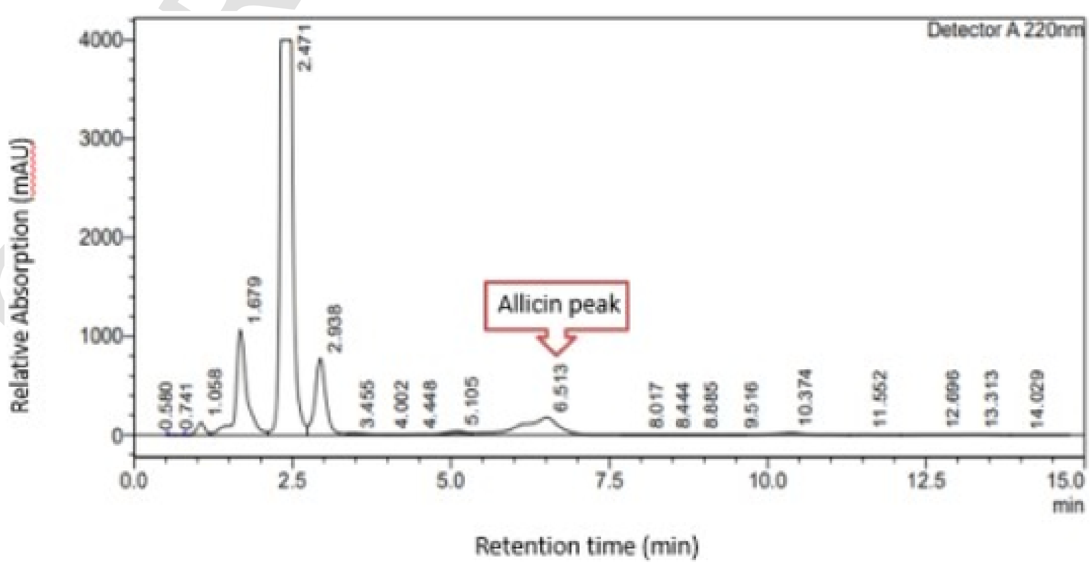

Fig. 2. Chromatogram of garlic extract with allicin standard.

Table 3
Allicin content (mg/g) in fresh sliced and dried garlic slices at different storage conditions (time and temperature).

Treatments**	Allicin content in fresh sliced garlic (mg/g) $	Allicin content in dried garlic slices (mg/g) $
Control	9.54 ± 0.03 ^{n}	9.54 ± 0.03 ^{a}
Trt 1	11.04± 0.02 ^{mA*}	6.68 ± 0.02 ^{bB}
Trt 2	26.34 ± 0.03 ^{jA}	6.51 ± 0.02 ^{cB}
Trt 3	54.78 ± 0.02 ^{aA}	6.34 ± 0.20 ^{dB}
Trt 4	53.56 ± 0.03 ^{bA}	5.99 ± 0.02 ^{eB}
Trt 5	53.34 ± 0.13 ^{cA}	5.75 ± 0.05 ^{fB}
Trt 6	52.53 ± 0.02 ^{dA}	5.45 ± 0.03 ^{gB}
Trt 7	50.78 ± 0.01^{eA}	5.36 ± 0.03 ^{hB}
Trt 8	50.34 ± 0.02 ^{fA}	5.34 ± 0.02 ^{iB}
Trt 9	47.84 ± 0.02 ^{gA}	5.29 ± 0.01 ^{jB}
Trt 10	32.94 ± 0.03 ^{hA}	4.4 ± 0.02 ^{kB}
Trt 11	27.8 ± 0.02 ^{iA}	4.31 ± 0.002^{lB}
Trt 12	18.08 ± 0.02 ^{kA}	4.08 ± 0.02 ^{mB}
Trt 13	10.57 ± 0.02 ^{lA}	3.77 ± 0.02 ^{nB}

$ All values are means of three replicates and calculated on dry basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

potent organosulfur compounds at room temperature in water (Locatelli *et al.*, 2015).

The concentration of allicin in sliced and crushed fresh garlic increased after that in the following treatments, Trt 2 (4 ºC, 10 min) and Trt 3 (20 ºC, 10 min), and then the concentrations of allicin in the treatments began to decrease. These results match findings by Nguyen et al. (2021) who found that the allicin content was around 8.3 mg/g at the first measurement (0.5 min), but after 5 min, the allicin concentration rose significantly. When we compared the treatments of fresh sliced garlic and fresh crushed garlic, we found that the amount of allicin in the first form is less, but it is more stable. This corresponds to Thuwapanichayanan et al. (2014), who confirmed that fresh garlic slices did not create as much allicin as crushed or diced garlic because allinase did not come into contact with alliin as frequently. The result, the content of allicin decreased with increasing time and temperature of storage (from zero time to first 10 mit the allicin content increase after that being decrease with time), and this shows a relation between the decrease in stability of allicin with increased temperature and time of storage, and the opposite is true. These results agree with Fujisawa et al. (2008), who found that the different conditions of temperature and time affect the stability of allicin, which is considered unstable. Also, examined the overall concentration of the three primary sulfur-containing amino acids in garlic genotypes, together with the associated alterations in their sulfoxide content over storage, and found a marked rise in the S-alk(en)ylcysteine sulfoxide content. Instead of the water loss, this rise was ascribed to the conversion of the matching γ-glutamyl dipeptides to sulfoxides (Horníčková *et al.*, 2010).

Table 3 shows that when we compare treatments of fresh sliced garlic with dried garlic slices, the allicin content of the first form is much higher. So, the shift in enzyme activity during the drying process may be responsible for the high reduction of allicin in dried garlic slices. Also, high temperatures may accelerate the degradation of allicin, which has been reported to be a heat-sensitive compound whose subsequent evaporation during drying was responsible for the loss (Zhou et al., 2016). Our results in dried treatments were within the range reported by Rahman et al. (2009), who showed allicin content in dried garlic is 4.932 mg/g. While drying garlic powder causes significant changes to the allinase, it still can convert alliin to allicin. The decrease of allicin in all treatments may be due to the natural variability of the degradation phenomenon and may also be attributed to the unstable allicin hydrolyzed and the decomposition to mercaptans, disulfides, trisulfides, and thiophenes (Henrıquez et al., 2014).

3.3. *Pyruvic acid content*

The mean of pyruvic acid content in all treatments is given in Tables 4 and 5, also Fig. 4. The remaining flavor aptitude is represented by enzymatic pyruvic acid, as reported by Ammarellou et al. (2022). It is precursors of numerous chemical compounds, including pigments, hormones, amino acids, and terpenoids and the research has shown that the amount of pyruvic acid in garlic cloves has a major impact on their quality during both the growth and development stage and the storage phase (Oku *et al.*, 2019; Wall & Corgan, 2019).

The results in tables 4 and 5 show that the content of pyruvic acid in the treatments differs according to the form of garlic (fresh sliced, fresh crushed, or dried slices). The pyruvic acid content varied substantially

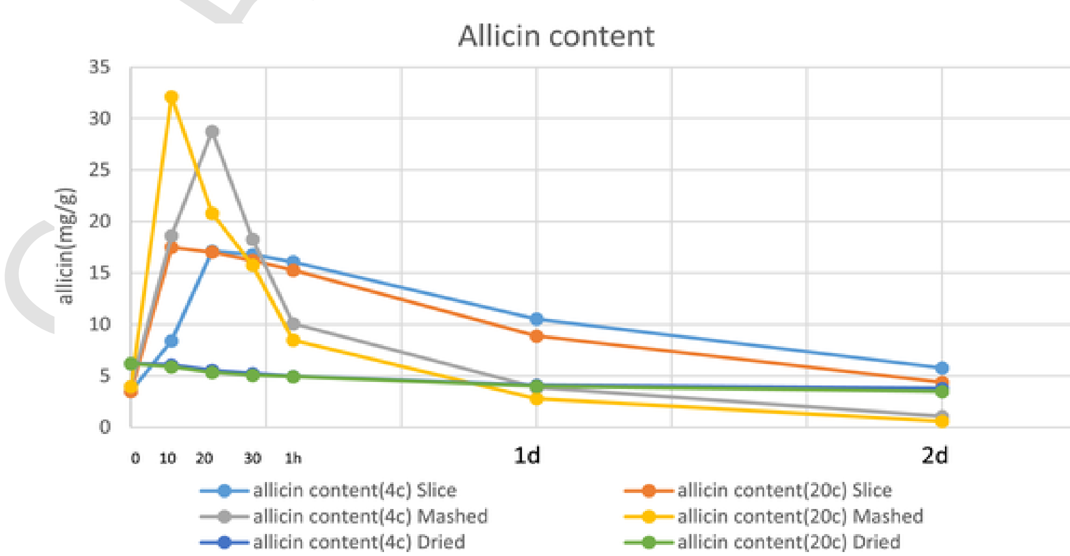

Fig. 3. Allicin content (mg/g) in fresh sliced, fresh mashed and dried garlic slices at different storage conditions (time and temperature).

Table 4
Pyruvic acid content (μmole/g) in fresh sliced and fresh crushed garlic at different storage conditions (time and temperature).

Treatments**	Pyruvic acid content in fresh sliced garlic (μmole/g)$^{\$}$	Pyruvic acid content in fresh crushed garlic (μmole/g)$^{\$}$
Control	3.9 ± 0.02 ^{m}	3.9 ± 0.02 ^{l}
Trt 1	4.20 ± 0.01 ^{lB*}	5.35 ± 0.05 ^{jA}
Trt 2	24.87 ± 0.02 ^{aB}	30.77 ± 0.08 ^{aA}
Trt 3	24.38 ± 0.03 ^{bB}	30.50 ± 0.02 ^{bA}
Trt 4	23.79 ± 0.02 ^{cB}	29.69 ± 0.01 ^{cA}
Trt 5	22.39 ± 0.02 ^{dB}	29.27 ± 0.03 ^{dA}
Trt 6	21.90 ± 0.10 ^{eB}	28.80 ± 0.10 ^{eA}
Trt 7	21.30 ± 0.10 f^{B}	28.19 ± 0.02 ^{fA}
Trt 8	20.86 ± 0.15 ^{gB}	27.88 ± 0.13 ^{gA}
Trt 9	19.80 ± 0.05 ^{gB}	27.08 ± 0.02 ^{gA}
Trt 10	19.55 ± 0.20 ^{hB}	26.26 ± 0.04 ^{hA}
Trt 11	19.15 ± 0.05 ^{iB}	25.35 ± 0.39 ^{iA}
Trt 12	18.81 ± 0.19 ^{jB}	24.59 ± 0.02 ^{jA}
Trt 13	17.38 ± 0.10 ^{kB}	23.38 ± 0.45 ^{kA}

$ All values are means of three replicates and calculated on a wet basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

Table 5
Pyruvic acid content (μmole/g) in fresh sliced and dried garlic slices at different storage conditions (time and temperature).

Treatments**	Pyruvic acid content in fresh sliced garlic (μmole/g) $^{\$}$	Pyruvic acid content in dried garlic slices (μmole/g) $^{\$}$
Control	12.2 ± 0.02 ^{m}	12.2 ± 0.02 ^{a}
Trt 1	13.1 ± 0.01 ^{lA*}	10.96 ± 0.01 ^{bB}
Trt 2	74.68 ± 0.02 ^{aA}	10.65 ± 0.01 ^{cB}
Trt 3	73.15 ± 0.03 ^{bA}	10.64 ± 0.02 ^{cdB}
Trt 4	71.3 ± 0.02 ^{cA}	10.56 ± 0.01 ^{deB}
Trt 5	70.05 ± 0.02 ^{dA}	10.54 ± 0.01 ^{eB}
Trt 6	68.5 ± 0.10 ^{eA}	10.51 ± 0.01 ^{egB}
Trt 7	66.6 ± 0.10 ^{fA}	10.47 ± 0.01 ^{fgB}
Trt 8	65.2 ± 0.15 ^{gA}	10.45 ± 0.02 ^{fghB}
Trt 9	64.7 ± 0.05 ^{gA}	10.39 ± 0.01 ^{ghB}
Trt 10	61.95 ± 0.20 ^{hA}	10.37 ± 0.02 ^{hiB}
Trt 11	59.9 ± 0.05 ^{iA}	10.29 ± 0.02 ^{ijB}
Trt 12	58.8 ± 0.19 ^{jA}	10.25 ± 0.02 ^{jkB}
Trt 13	57.5 ± 0.10 ^{kA}	10.12 ± 0.01 ^{kB}

$ All values are means of three replicates and calculated on a dry basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

across all the treatments, with the highest value being 30.77 μmol/g (wet basis) in fresh crushed garlic in Trt 2 (4 ºC, 10 min storage). Based on the results of our study, the highest values of pyruvic acid were found in fresh crushed garlic, followed by fresh sliced, and dried slices. According to the results shown in table 4, the amount of pyruvic acid in fresh (sliced and crushed) in Trt 1(20 ºC, 0 min storage) is low, and reached its highest value in Trt 2 (4 ºC, 10 min storage), and then begins to gradually decrease with the passage of time and the increase in temperature, as confirmed by Metrani et al. (2018). Concerning the pyruvic acid content in dried garlic, based on the results of our study, all treatments had a low percentage of pyruvic acid content and this decrease might be caused by the thermal process. Loss of pungency in garlic may be caused by the destruction of precursors and partial inactivation of the enzyme allinase under drying conditions (Ratti *et al.*, 2007).

3.4. Total phenol content

The mean of total phenol content (TPC) in fresh (sliced and crushed) and dried garlic slices with the effect of different storage conditions (time and temperature) is given in tables 6 and 7 (not for the same result, table 6 compare TPC between fresh sliced garlic and fresh crushed garlic but table 7 compare TPC between fresh sliced garlic and dried garlic). The total phenolic concentration of all dried treatments was considerably less than that of fresh treatments (sliced and crushed). Heat treatment might create permanent chemical changes and a reduction in total phenolic compounds since they are heat-labile (Djendoubi et al., 2012). The TPC is affected by several variables, including temperature, light, water, and nutrient availability (Bystrická et al., 2013). As shown in Tables 6 and 7, the result matches the study done by Pedisić et al. (2018), who found that TPC in crushed garlic at room temperature for different exposure times (0, 2, 5, and 8 min) decreased. Given that TPC acts as an antioxidant, its possible oxidation to quinones can be used to explain why TPC levels decreased during storage (Jastrzebski et al., 2007). During processing and storage, many polyphenols are unstable and highly susceptible to oxidation and degradation (Chandra et al., 2021). When plant cells are destroyed, the polyphenol oxidation and degradation reactions of polyphenols will be released and catalyzed, releasing the polyphenol oxidase, polyphenol peroxidase, polyphenol glycosidase, and polyphenol esterase in fruits and vegetables (Montoya et al., 2021). This elucidates the rationale behind the elevated levels of total phenol content observed in whole garlic, followed by sliced garlic, and followed by crushed garlic.

3.5. Antioxidant activity

The mean of antioxidant activity in fresh (sliced and crushed) and dried garlic slices with the effect of different storage conditions (time and temperature) is presented in Tables 8 and 9. There were significant variances in antioxidant activity between garlic forms. The antioxidant content in fresh treatments ranged from 17.34 % to 53.89 %, and in dried treatments ranged from 13.18 % to 19.56 %. Like the results shown with Chen *et al.* (2013) that prove that antioxidant activity ranges from 3.6 % to 45.6 %. As shown in Table 8 and Table 9, the higher antioxidant activity content in fresh sliced treatments was found in Trt 1 (53.89 %), and the lowest AA was found in Trt 13 (27.22 %). The higher antioxidant activity content in fresh mashed treatments was found in Trt 1 (34.65 %) and the lowest AA was found in Trt 13 (17.34 %). The higher antioxidant activity content in dried slices treatments was found in Trt 1 (19.56 %), and the lowest AA was found in Trt 13 (13.18 %).

Various parameters, such as heat treatment and extracted solvent, can alter the antioxidant activity of garlic (Songsungkan & Chanthai, 2014). The antioxidant activity comes from total phenol and organosulfur compounds (allyl cysteine, alliin, allicin, and allyl disulfide) in garlic. Total phenolic and antioxidant activity have a positive relationship (Kyung, 2012), and the thiosulfinates, in particular allicin, are capable of scavenging the peroxyl radical and serving as antioxidants (Okada *et al.*, 2005). Temperature caused chemical oxidation and released oxidative and hydrolytic enzymes that might degrade the antioxidant chemicals in 46 vegetables, and air exposure also accelerated oxidation processes and enzyme activity (Altemimi *et al.*, 2017).

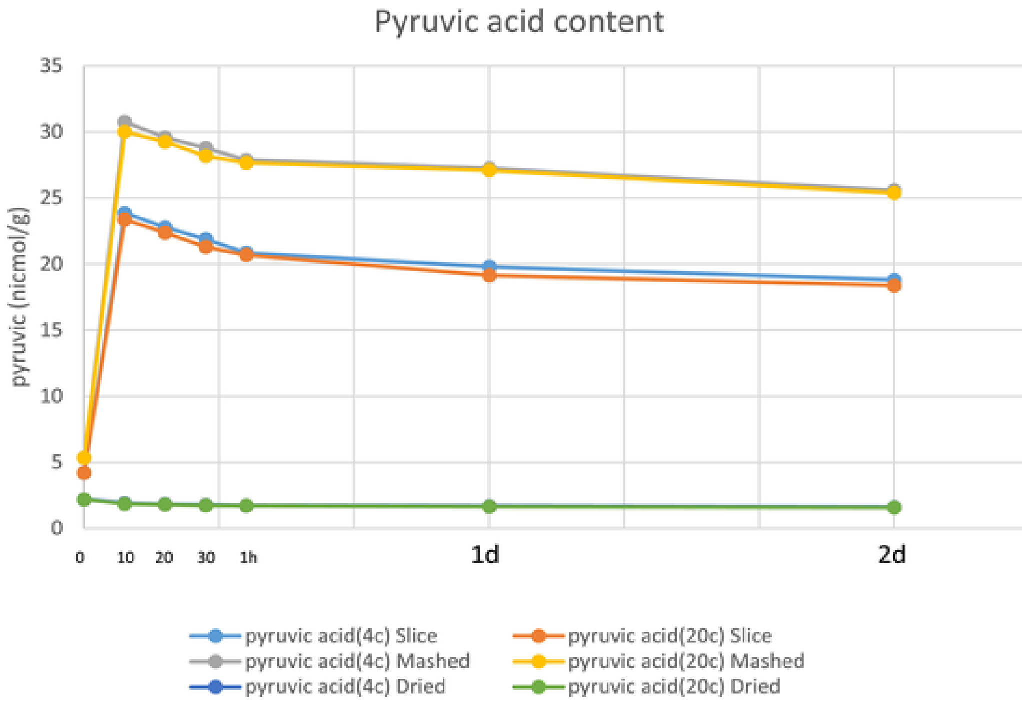

Fig. 4. Pyruvic acid content (μmole/g) in fresh sliced, fresh mashed and dried garlic slices at different storage conditions (time and temperature).

Table 6
Total phenol content (mg GAE/100 g) in fresh sliced and fresh crushed garlic at different storage conditions (time and temperature).

Treatments**	Total phenol content in fresh sliced garlic (mg GAE/100 g) $	Total phenol content in fresh crushed garlic (mg GAE/100 g) $
Control	29.10 ± 0.01^{a}	29.10 ± 0.01 ^{a*}
Trt 1	28.90 ± 0.02 ^{bA}	27.30 ± 0.10 ^{bB}
Trt 2	28.80 ± 0.02 ^{bcA}	24.87 ± 0.03 ^{cB}
Trt 3	28.71 ± 0.01 ^{cA}	24.73 ± 0.03 ^{dB}
Trt 4	28.50 ± 0.01 ^{dA}	24.57 ± 0.02 ^{eB}
Trt 5	28.30 ± 0.02 ^{eA}	24.40 ± 0.10 ^{fB}
Trt 6	28.09 ± 0.02 ^{fA}	24.23 ± 0.03 ^{gB}
Trt 7	27.80 ± 0.02 ^{gA}	23.60 ± 0.10 ^{hB}
Trt 8	27.50 ± 0.02 ^{hA}	23.30 ± 0.10 ^{iB}
Trt 9	27.12 ± 0.04 ^{iA}	23.03 ± 0.01 ^{jB}
Trt 10	26.66 ± 0.05 ^{jA}	22.77 ± 0.03 ^{kB}
Trt 11	26.22 ± 0.01 ^{kA}	22.24 ± 0.01 ^{lB}
Trt 12	26.28 ± 0.02 ^{kA}	21.90 ± 0.02 ^{mB}
Trt 13	25.70 ± 0.10 ^{lA}	21.20 ± 0.01 ^{nB}

$ All values are means of three replicates and calculated on a wet basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

Table 7
Total phenol content (mg GAE/100 g) in fresh sliced and dried garlic slices at different storage conditions (time and temperature).

Treatments**	Total phenol content in fresh sliced garlic (mg GAE/100 g) $	Total phenol content in dried garlic slices (mg GAE/100 g) $
Control	91.05 ± 0.01 ^{a}	91.05 ± 0.01 ^{a}
Trt 1	90.42 ± 0.02 ^{bA}	18.98 ± 0.05 ^{bB}
Trt 2	90.11 ± 0.02 b^{cA}	18.83 ± 0.02 ^{cB}
Trt 3	89.83 ± 0.01 ^{cA}	18.78 ± 0.02 ^{dB}
Trt 4	89.17 ± 0.01 ^{dA}	18.60 ± 0.02 ^{deB}
Trt 5	88.54 ± 0.02 ^{eA}	18.50 ± 0.01 ^{efB}
Trt 6	87.89 ± 0.02 ^{fA}	18.46 ± 0.01 ^{efgB}
Trt 7	86.98 ± 0.02 ^{gA}	18.32 ± 0.02 ^{fgB}
Trt 8	86.04 ± 0.02 ^{hA}	18.25 ± 0.01 ^{fgB}
Trt 9	85.60 ± 0.04 ^{iA}	18.09 ± 0.01 ^{gB}
Trt 10	82.75 ± 0.05 ^{jA}	17.49 ± 0.02 ^{hB}
Trt 11	82.41 ± 0.01 ^{kA}	17.28 ± 0.02 ^{iB}
Trt 12	82.22 ± 0.02 ^{kA}	16.74 ± 0.03 ^{jB}
Trt 13	80.41 ± 0.10 ^{lA}	16.50 ± 0.01 ^{kB}

$ All values are means of three replicates and calculated on a dry basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

3.6. *Consumer acceptance of garlic extract*

As the hedonic scale results showed in Table 10, there were some significant differences ($P < 0.05$) between all samples for overall appearance, overall aroma, overall pungency, and overall flavor. while there were no differences between samples for overall color compared to the control. The results of consumer testing as hedonic scale showed that the highest value of overall appearance was found in sample C3 'hummus with crushed garlic at 10 min 20 ºC' (7.63), the highest value of overall aroma found in sample C3 'hummus with crushed garlic at 10 min 20 ºC' (7.63), the highest value of overall flavor found in sample C3 'hummus with crushed garlic at 10 min 20 ºC' (7.53), the highest value of overall pungency found in sample C3 'hummus with crushed garlic at 10 min 20 ºC' (7.63). Table 11 shows the just-about-right scale

Table 8
Total phenol content (mg GAE/100 g) in fresh sliced and fresh crushed garlic at different storage conditions (time and temperature).

Treatments**	Antioxidant activity (%) in fresh sliced garlic $	Antioxidant activity (%)in fresh crushed garlic $
Control	29.10 ± 0.01^{a}	29.10 ± 0.01^{a*}
Trt 1	28.90 ± 0.02^{bA}	27.30 ± 0.10^{bB}
Trt 2	28.80 ± 0.02^{bcA}	24.87 ± 0.03^{cB}
Trt 3	28.71 ± 0.01^{cA}	24.73 ± 0.03^{dB}
Trt 4	28.50 ± 0.01^{dA}	24.57 ± 0.02^{eB}
Trt 5	28.30 ± 0.02^{eA}	24.40 ± 0.10^{fB}
Trt 6	28.09 ± 0.02^{fA}	24.23 ± 0.03^{gB}
Trt 7	27.80 ± 0.02^{gA}	23.60 ± 0.10^{hB}
Trt 8	27.50 ± 0.02^{hA}	23.30 ± 0.10^{iB}
Trt 9	27.12 ± 0.04^{iA}	23.03 ± 0.01^{jB}
Trt 10	26.66 ± 0.05^{jA}	22.77 ± 0.03^{kB}
Trt 11	26.22 ± 0.01^{kA}	22.24 ± 0.01^{lB}
Trt 12	26.28 ± 0.02^{kA}	21.90 ± 0.02^{mB}
Trt 13	25.70 ± 0.10^{lA}	21.20 ± 0.01^{nB}

$ All values are means of three replicates and calculated on a wet basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

Table 9
Antioxidant activity of fresh sliced and dried garlic slices at different storage conditions (time and temperature).

Treatments**	Antioxidant activity (%) in fresh sliced garlic $	Antioxidant activity (%) in dried garlic slices $
Control	91.05 ± 0.01^{a}	91.05 ± 0.01^{a}
Trt 1	90.42 ± 0.02^{bA}	18.98 ± 0.05^{bB}
Trt 2	90.11 ± 0.02 b^{cA}	18.83 ± 0.02^{cB}
Trt 3	89.83 ± 0.01^{cA}	18.78 ± 0.02^{dB}
Trt 4	89.17 ± 0.01^{dA}	18.60 ± 0.02^{deB}
Trt 5	88.54 ± 0.02^{eA}	18.50 ± 0.01^{efB}
Trt 6	87.89 ± 0.02^{fA}	18.46 ± 0.01^{efgB}
Trt 7	86.98 ± 0.02^{gA}	18.32 ± 0.02^{fgB}
Trt 8	86.04 ± 0.02^{hA}	18.25 ± 0.01^{fgB}
Trt 9	85.6 ± 0.04^{iA}	18.09 ± 0.01^{gB}
Trt 10	82.75 ± 0.05^{jA}	17.49 ± 0.02^{hB}
Trt 11	82.41 ± 0.01^{kA}	17.28 ± 0.02^{iB}
Trt 12	82.22 ± 0.02^{kA}	16.74 ± 0.03^{jB}
Trt 13	80.41 ± 0.10^{lA}	16.50 ± 0.01^{kB}

$ All values are means of three replicates and calculated on a dry basis and represent Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$)No significant differences between all the treatments *capital letter = Garlic differs according to its form, small letter= Garlic differs according to its treatments **Control= fresh whole garlic peeled, Trt 1= Zero time, Trt 2 = 10 min at 4 ºC, Trt 3 = 10 min at 20 ºC, Trt 4 = 20 min at 4 ºC, Trt 5 = 20 min at 20 ºC, Trt 6 = 30 min at 4 ºC, Trt 7 = 30 min at 20 ºC, Trt 8 = 1 hr at 4 ºC, Trt 9 = 1 hr at 20 ºC, Trt 10= 1 day at 4 ºC, Trt 11= 1 day at 20 ºC, Trt 12= 2 day at 4 ºC, Trt 13= 2 day at 20 ºC.

according to flavor, aroma, and pungency. The highest value of flavor, aroma, and pungency are found in sample D4 'hummus with dried garlic at 20 min 4 ºC', while the lowest value was found in 'hummus with crushed garlic at 10 min 4 ºC' (1.13). These data also agreed with Al-Nabulsi et al. (2022), who found that hummus without garlic was rated 6.9 in color, 6.9 in aroma, 6.9 in overall flavor, and 6.7 in Overall impression. In the same study, when adding 1 % garlic to hummus, the sample was rated 6.9 in color, 5.9 in aroma, 5.9 in overall flavor, and 4.5 in the overall impression.

Table 10
Consumer scores of the effect condition (time and temperatures) of garlic sample in hummus (Hedonic scale@).

Samples**	Overall color	Overall aroma	Overall Flavor	Overall pungency	Overall Appearance
Control	5.38 ± 0.2^{a*}	6.20 ± 0.1^{cd}	5.63 ± 0.5^{d}	5.10 ± 0.3^{e}	5.50 ± 0.2^{d}
S1	5.45 ± 0.2^{a}	6.00 ± 0.3^{d}	6.30 ± 0.4^{c}	6.05 ± 0.2^{d}	6.00 ± 0.2^{c}
S2	5.25 ± 0.3^{a}	6.50 ± 0.1^{bc}	6.63 ± 0.3^{bc}	6.35 ± 0.5^{bcd}	6.50 ± 0.3^{b}
S3	5.48 ± 0.1^{a}	6.90 ± 0.3^{b}	6.90 ± 0.3^{b}	6.90 ± 0.3^{b}	6.90 ± 0.1^{b}
S4	5.45 ± 0.1^{a}	4.83 ± 0.2^{f}	4.83 ± 0.2^{e}	4.83 ± 0.2^{e}	4.83 ± 0.2^{e}
C1	5.38 ± 0.3^{a}	6.50 ± 0.3^{b}	6.75 ± 0.3^{bc}	6.75 ± 0.3^{bc}	6.75 ± 0.3^{b}
C2	5.38 ± 0.2^{a}	6.75 ± 0.3^{b}	6.50 ± 0.3^{bc}	6.50 ± 0.3^{bc}	6.50 ± 0.3^{b}
C3	5.38 ± 0.1^{a}	7.63 ± 0.4^{a}	7.53 ± 0.4^{a}	7.63 ± 0.4^{a}	7.73 ± 0.4^{a}
C4	5.38 ± 0.2^{a}	3.63 ± 0.2^{j}	3.53 ± 0.2^{f}	3.63 ± 0.2^{f}	3.63 ± 0.2^{f}
D1	5.38 ± 0.2^{a}	5.59 ± 0.2^{e}	5.59 ± 0.2^{d}	6.20 ± 0.1^{cd}	6.70 ± 0.2^{b}
D2	5.38 ± 0.3^{a}	5.45 ± 0.2^{e}	5.45 ± 0.2^{d}	6.25 ± 0.1^{cd}	6.75 ± 0.2^{b}
D3	5.38 ± 0.3^{a}	5.40 ± 0.2^{e}	5.40 ± 0.2^{d}	6.20 ± 0.1^{cd}	6.70 ± 0.2^{b}
D4	5.38 ± 0.1^{a}	5.55 ± 0.2^{e}	5.55 ± 0.2^{d}	6.25 ± 0.1^{cd}	6.75 ± 0.2^{b}

Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$).
No significant differences between all the treatments.
*small letter= Garlic differs according to its treatments.
**Samples= hummus samples, Control= hummus without garlic, S1= hummus with fresh sliced garlic after Trt 1, S2= hummus with fresh sliced garlic after Trt 2, S3= hummus with fresh sliced garlic after Trt 3, S4= hummus with fresh sliced garlic after Trt 4, C1= hummus with fresh crushed garlic after Trt 1, C2= hummus with fresh crushed garlic Trt 2, C3= hummus with fresh crushed garlic Trt 3, C4= hummus with fresh crushed garlic Trt 4, D1= hummus with dried garlic after Trt 1, D2= hummus with dried garlic after Trt 2, D3= hummus with dried garlic after Trt 3, D4= hummus with dried garlic after Trt 4.
**Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$).
@ Hedonic scales: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 =like very much, 9 =like extremely.

4. Conclusions

This study investigated different forms of garlic (freshly sliced, freshly crushed, and dried slices). The rate of allicin formation was significantly affected by temperature, and fresh mashed garlic had more content of allicin and pyruvic acid than fresh sliced garlic. On the other hand, fresh sliced garlic has a higher content of allicin and pyruvic acid than dried garlic slices. Optimum time and temperature in which a large amount of allicin is obtained after 10 min of mashing fresh garlic at room temperature. Total phenol content, antioxidant activity, pyruvic acid, and allicin decrease with increased time and temperature. For sensory attributes, fresh mashed garlic after 10-minute storage at 20 ºC has the most acceptable pungency attributes.

Uncited references

Henriquez et al., 2014, M.S. Rahman, 2007.

Table 11
Consumer scores of the effect condition (time and temperatures) of garlic sample in hummus (Just about right scale@).

Samples**	Pungency	Flavor	Aroma
Control	3.38 ± 0.4 c*	3.38 ± 0.4 c	3.38 ± 0.4 c
S1	4.50 ± 0.4 a	3.75 ± 0.4 b	3.75 ± 0.4 b
S2	2.80 ± 0.1 d	2.80 ± 0.1 d	2.80 ± 0.1 d
S3	3.83 ± 0.4 b	3.83 ± 0.4 b	3.83 ± 0.4 b
S4	3.88 ± 0.1 b	3.88 ± 0.1 b	3.88 ± 0.1 b
C1	2.40 ± 0.2 e	2.40 ± 0.4 e	2.40 ± 0.4 e
C2	1.13 ± 0.3 f	1.13 ± 0.3 f	1.13 ± 0.3 f
C3	2.20 ± 0.3 e	2.20 ± 0.1 e	2.20 ± 0.1 e
C4	2.40 ± 0.2 e	2.40 ± 0.4 e	2.40 ± 0.4 e
D1	4.60 ± 0.4 a	4.60 ± 0.4 a	4.16 ± 0.4 a
D2	4.62 ± 0.4 a	4.62 ± 0.4 a	4.17 ± 0.4 a
D3	4.65 ± 0.4 a	4.65 ± 0.4 a	4.18 ± 0.4 a
D4	4.68 ± 0.4 a	4.68 ± 0.4 a	4.19 ± 0.4 a

Means ± SD in the same column with the same letter are not significantly different ($P \leq 0.05$).
No significant differences between all the treatments.
*small letter = Garlic differs according to its treatments.
**Samples= hummus samples, Control= hummus without garlic, S1= hummus with fresh sliced garlic after Trt 1, S2= hummus with fresh sliced garlic after Trt 2, S3= hummus with fresh sliced garlic after Trt 3, S4= hummus with fresh sliced garlic after Trt 4, C1= hummus with fresh crushed garlic after Trt 1, C2= hummus with fresh crushed garlic Trt 2, C3= hummus with fresh crushed garlic Trt 3, C4= hummus with fresh crushed garlic Trt 4, D1= hummus with dried garlic after Trt 1, D2= hummus with dried garlic after Trt 2, D3= hummus with dried garlic after Trt 3, D4= hummus with dried garlic after Trt 4.
@ Just about right scale for flavor: 1 = too much flavor, 2 = much flavor, 3 = just about right, 4 = light flavor, 5 = normal flavor.
@ Just about right scale for aroma: 1 = too much aroma, 2 = much aroma, 3 = just about right, 4 = light aroma, 5 = normal aroma.
@ Just about right scale for pungency: 1 = too much pungent, 2 = much pungent, 3 = just about right, 4 = light pungent, 5 = normal pungent.

CRediT authorship contribution statement

Taha Rababah: Writing – original draft, Supervision. **Muhammad Al-U'datt:** Methodology. **Malak Angor:** Data curation. **Ahmad Alsaad:** Validation. **Yazan Akkam:** Resources. **Sana Gammoh:** Resources. **Ghazi Maghableh:** Formal analysis. **Tamara Smadi:** Investigation. **Ali Almajwal:** Funding acquisition. **Sevil Yücel:** Methodology. **Bandar N. Hamadneh:** Data curation. **Vaida Bartkutė-Norkūnienė:** Resources. **Muhammad Azam:** Methodology. **Numan AL-Rayyan:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The author is an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for *[Journal name]* and was not involved in the editorial review or the decision to publish this article.

Data availability

Data is available at the following link: https://data.mendeley.com/datasets/scgr52tw9h/1.

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Data availability

Data is available at the following link: https://data.mendeley.com/datasets/scgr52tw9h/1.

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