UNIVERSIDAD DEL ZULIA
Serbiluz
Sistema de Servicios Bibliotecarios y de Información
Biblioteca Digital
Repositorio Académico
REVISTA de la FACULTAD de AGRONOMIA

Modified atmosphere packaging of an endemic garlic species, *Allium Tuncelianum*

Envasado en atmósfera modificada de una especie endémica de ajo, *Allium Tuncelianum*

Embalagem em atmosfera modificada de uma espécie endêmica de alho, *Allium Tuncelianum*

Alper Güven[1]*
Nida Beğboğa[2]

Rev. Fac. Agron. (LUZ). 2025, 42(3): e254240
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v42.n3.XI

Food technology

Associate editor: Dra. Gretty R. Ettiene Rojas
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela.

[1]Faculty of Fine Arts & Design and Architecture/Gastronomy and Culinary Arts Munzur Uni, Tunceli, Turkey.
[2]Institute of Graduate Education, Food Technology, Munzur Uni, Tunceli, Turkey.

Received: 22-04-2025
Accepted: 31-07-2025
Published: 24-08-2025

Keywords:
Allium sativum
Modified atmosphere packaging
MAP
Minimally processed vegetables

Abstract

Allium tuncelianum is an important endemic food ingredient widely used in Tunceli cuisine, Turkey, because of its health benefits, and its less tangy unique flavor and aroma compared to cultured garlic. In the present study, modified atmosphere packaging (MAP) of *Allium tuncelianum*, and changes in its quality during 28 days of refrigerated storage were investigated. This study is the only study on minimal processing of *Allium tuncelianum*. Effect of the initial gas mixture during storage was investigated using two distinct initial gas mixtures A and B: 5 % O_2, 5 % CO_2, 90 % N_2, and 3 % O_2, 8 % CO_2, 89 moles N_2 on molar basis, respectively. Samples were analyzed every seven days with respect to weight loss, dry matter, water activity, total phenolic content, pH, titratable acidity, ash content, color, degree of sprouting, and texture profile. Modified atmosphere packaging resulted in 3.7- 4.45 g.100 g^{-1} weight loss compared with 20.67 g.100 g^{-1} in the control group stored at room temperature and humidity. No sprouting was detected in the control group, whereas fractional sprouting was 0.875 for the MAP samples. Therefore, the key parameter related with MAP storage of *Allium tuncelianum* seems to be the moisture content of the packaging atmosphere. MAP with moisture adsorbant packages is a promising method for maintaining the freshness of *Allium tuncelianum* providing a marketing strategy for this endemic ingredient.

*Corresponding author: agueven@munzur.edu.tr

Resumen

Allium tuncelianum es un importante ingrediente alimentario endémico ampliamente utilizado en la cocina de Tunceli, Turkey, debido a sus beneficios para la salud y a su sabor y aroma únicos, menos picantes, en comparación con el ajo cultivado. En el presente estudio, se investigaron el envasado en atmósfera modificada (MAP) de *Allium tuncelianum* y los cambios en su calidad durante 28 días de almacenamiento refrigerado. Este estudio es el único estudio sobre el procesamiento mínimo de *Allium tuncelianum.* El efecto de la mezcla de gases inicial durante el almacenamiento se investigó utilizando dos mezclas de gases iniciales distintas, A y B: 5 % O_2, 5 % CO_2 90 %N_2, y 3 % O_2, 8 % CO_2, 89 % N_2, respectivamente. Las muestras se analizaron cada siete días con respecto a pérdida de peso, materia seca, actividad de agua, contenido fenólico total, pH, acidez titulable, contenido de cenizas, color, grado de brotación y perfil de textura. El envasado en atmósfera modificada dio como resultado una pérdida de peso de 3,7 a 4,45 g.100 g^{-1} en comparación con 20,67 g.100 g^{-1} en el grupo de control almacenado a temperatura y humedad ambiente. No se detectó ningún brote en el grupo de control, mientras que el brote fraccional fue de 0,875 para las muestras de MAP. Por lo tanto, el parámetro clave relacionado con el almacenamiento MAP de *Allium tuncelianum* parece ser el contenido de humedad de la atmósfera del envasado. MAP con paquetes de adsorbentes de humedad es un método prometedor para mantener la frescura de *Allium tuncelianum* y proporciona una estrategia de marketing para este ingrediente endémico.

Palabras clave: *Allium sativum*, envasado en atmósfera modificada, MAPA, verduras mínimamente procesadas.

Resumo

Allium tuncelianum é um importante ingrediente alimentar endêmico amplamente utilizado na culinária Tunceli, Turkey, por causa de seus benefícios à saúde e seu sabor e aroma únicos e menos picantes em comparação com o alho cultivado. No presente estudo foram investigadas embalagens em atmosfera modificada (MAP) de *Allium tuncelianum* e alterações na sua qualidade durante 28 dias de armazenamento refrigerado. Este estudo é o único sobre processamento mínimo de *Allium tuncelianum*. O efeito da mistura inicial de gases durante o armazenamento foi investigado usando duas misturas iniciais distintas de gases A e B: 5 % O_2, 5 % CO_2, 90 % N_2 e 3 % O_2, 8 % CO_2, 89 % N_2, respectivamente. As amostras foram analisadas a cada sete dias quanto à perda de peso, matéria seca, atividade de água, teor de fenólicos totais, pH, acidez titulável, teor de cinzas, cor, grau de brotação e perfil de textura. A embalagem em atmosfera modificada resultou em perda de peso de 3,7-4,45 g.100 g^{-1}, em comparação com 20,67 g.100 g^{-1} no grupo controle armazenado em temperatura e umidade ambiente. Nenhuma brotação foi detectada no grupo controle, enquanto a brotação fracionada foi de 0,875 para as amostras de MAP. Portanto, o parâmetro chave relacionado ao armazenamento MAP de *Allium tuncelianum* parece ser o teor de umidade da atmosfera da embalagem. O MAP com pacotes adsorventes de umidade é um método promissor para manter o frescor do *Allium tuncelianum*, fornecendo uma estratégia de marketing para este ingrediente endêmico.

Palavras-chave: *Allium sativum*, embalagens com atmosfera modificada, MAPA, vegetais minimamente processados.

Introduction

Garlic (*Allium sativum* L.) is an ancient plant valued for both culinary and medicinal uses (Thakur *et al*., 2024; Ezeorba *et al*., 2024). It contains over 200 phytochemicals, including 33 sulfur compounds, phenolics, bioactive proteins, and peptides (Martins *et al*., 2016; Ezeorba *et al*., 2024). Garlic is also characterized by phenolic compounds and the main group consists of phenolic acids (mainly as caffeic acids), followed by flavonoids (mainly as quercetin) (Pedisi´c *et al*., 2018).

Garlic is rich in germanium, zinc, and vitamins A, B1, and C (El-Saadony *et al*., 2024). Its distinct aroma and bioactivity come from volatile thiosulfonates, mainly alliin, which converts to allicin when garlic is crushed. It has antibacterial, antithrombotic, anti-arthritic, hypolipidemic, hypoglycemic, and anti-tumor properties (Mondal *et al*., 2022). Garlic is widely used in cooking, both as a key ingredient and flavoring (Çam and Çelik, 2024). Garlic is a relatively less perishable product than most fruits and vegetables because it quickly loses moisture through its skin at uncontrolled storage conditions. However, garlic cloves may dry out or sprout in a short time depending on seasonal variations in temperature and humidity of storage (Vázquez-Barrios *et al*., 2006). For commercial garlic the weight and moisture loss are key quality factors (Shagun *et al*., 2024). With a moisture content of 65 % (w.b), garlic is prone to enzymatic and microbial spoilage, leading to sprouting and rotting (EL-Mesery *et al*., 2022).

There are 500 known Allium species, with 170 in Turkey, 40 % of which are endemic. *Allium tuncelianum*, a wild, single-clove garlic endemic to Tunceli (39°06′23″N 9°32′50″E, 914–1850 m altitude), grows abundantly on the slopes of the Munzur Mountains. *Allium tuncelianum* is a sibling of commercial garlic (*Allium sativum*), with a similar phytochemical profile (Takim, 2020). It has a milder garlic aroma (Yumrutaş *et al*., 2009) making it suitable for fresh consumption as well as industrial use; thus, it has high potential as a culinary ingredient if cultivated (Takim, 2020; Hirschegger *et al*., 2010).

Fresh fruits and vegetables are the most suitable for minimal processing (Bansal *et al*., 2015). Respiration continues after harvest for fruits and vegetables, using available carbohydrates, proteins, fats, organic acids, and other organic compounds as substrates that produce water and carbon dioxide. Therefore, respiration results in weight loss due to the loss of metabolizable nutritive substances, causing loss of flavor, aroma, and color (Ishangulyyev *et al*., 2019). Modified atmosphere packaging (MAP) is becoming more and more popular for preserving freshness and extending the storage and shelf life of fresh fruits and vegetables (Ward, 2016). MAP aims to slow down respiration as well as the growth of aerobic microflora by replacing air with a suitable gas mixture consisting of oxygen, carbon dioxide, and nitrogen (Chaix *et al*., 2015; Sandhya, 2010). A lower oxygen content than air, together with carbon dioxide, slows down respiration. Carbon dioxide also has an antimicrobial effect by inhibiting the growth of mesophilic aerobic microflora (Sivertsvik *et al*., 2002). The growth of mesophilic aerobic microflora and enzymatic activity are further suppressed by refrigerated storage of the packages (Kargwal *et al*., 2020; Wani *et al*., 2015; González-Buesa *et al*., 2009). In MAP, the composition of the initial gas mixture depends on the rate of respiration and gas permeability of the packaging material. The packaging material should be selected such that the rate of oxygen consumption owing to respiration is equal to the rate of oxygen diffusion through the packaging material.

Similarly, the rate of carbon dioxide production should be equal to the rate of diffusion through the packaging material (Rashvand *et al*., 2024; Kargwal, 2020; Chen *et al*., 2019; Takim, 2020; Hirschegger *et al*., 2010). Typical MAP packaging materials include polypropylene (PP), polyester, polyvinyl chloride (PVC), nylon polyamide, (PA), polyethylene terephtalate (PET), oriented polypropylene (OPP), ethylene vinyl acetate (EVA), copolymerized ethylene vinyl alcohol (EVOH), and polystyrene (Davies, 1999; Phillips, 1996). Studies on cultivated garlic have shown that various packaging films like polyolefin, polyethylene (low/high-density), polyamide-polyethylene copolymers, and PVC are suitable for MAP storage (Singh *et al*., 2019; Li *et al*., 2010). For commercial garlic, a wide range of gas mixtures ranging between 5 - 25 % CO_2 and 0 – 5 % O_2 have been used (Venu Madhav *et al*., 2016; Cantwell *et al*., 2003; Kang and Lee, 1999). These studies showed that color change was minimal, and sprouting and microbial deterioration could be suppressed during 3 - 5 weeks of refrigerated MAP storage (Li *et al*., 2010; Dronachari *et al*., 2010; Cantwell *et al*., 2003; Kang and Lee, 1999).

The aim of this study was to investigate the effect of the initial composition of the gas mixture on the quality parameters of *Allium tuncelianum* during active MAP storage. The present study is the only study on minimal processing of *Allium tuncelianum* to increase the added value of this endemic product, and to develop a marketing strategy to support the economic livelihood of the local population through commercilization of this healthy culinary ingredient.

Materials and methods

Plant Material

Allium tuncelianum (figure 1), collected by local ovacık population in the Tunceli region, Turkey, from September to October 2022, was used. Samples were classified by size (32 ± 2, 36 ± 2, 41 ± 2, and 45 ± 2 mm) using a digital caliper and deskinned carefully to avoid damage. Plants with no tissue damage were selected from the bulk. Selected *Allium tuncelianum* samples were classified according to size as: 32 ± 2, 36 ± 2, 41 ± 2, and 45 ± 2 mm using a digital caliper (Asimeto, Hong Kong) since mass transfer induced drying is size dependent. Classified garlic samples were peeled by using a suitable knife and the peeled samples were weighed (AND, FX-3000I, Tokyo, Japan) Weighed samples (50±2 g) were grouped into packaging sets and divided into three treatment groups. The gas compositions were selected in accordance with Venu Madhav *et al*. (2016) Groups A and B were subjected to gas mixtures of 5 % O_2, 5 % CO_2, 90 % N_2, and 3 % O_2, 8 % CO_2, 89 % N_2, respectively, while the control group was kept at room temperature in uncontrolled storage conditions (23.0 ± 0.5°C, 45 ± 5% RH). Fresh samples were analyzed for dry matter, water activity, total phenolic content, pH, titratable acidity, ash content, color, sprouting degree, and texture profiles. Packaging was done in standard PET-PE copolymer containers sealed with PP films (Fig. 1d). Polypropylene used in sealing the packaged had an oxygen transfer ratio of $cm^3.m^{-2}$ day <4, and water vapor transfer ratio of (30 ^oC – 90 % RH) $g.m^{-2}.day^{-1}$ <15.

Application of MAP

Samples were packed using a stainless steel 304 laboratory size MAP equipment (Lipovak, KV-500, Sakarya, Turkey) with a volume of 1046454 cm^3, equipped with a vacuum pump (P.V.R., EM20, Italy) that can evacuate down to 2 mbars, and gas mixture regulating accesories. (figure 2). MAP was initiated by evacuating the packages for 10 s. The initial gas mixture was then applied to the packaging medium, followed by heat sealing. Samples were stored at 4 ˚C after MAP.

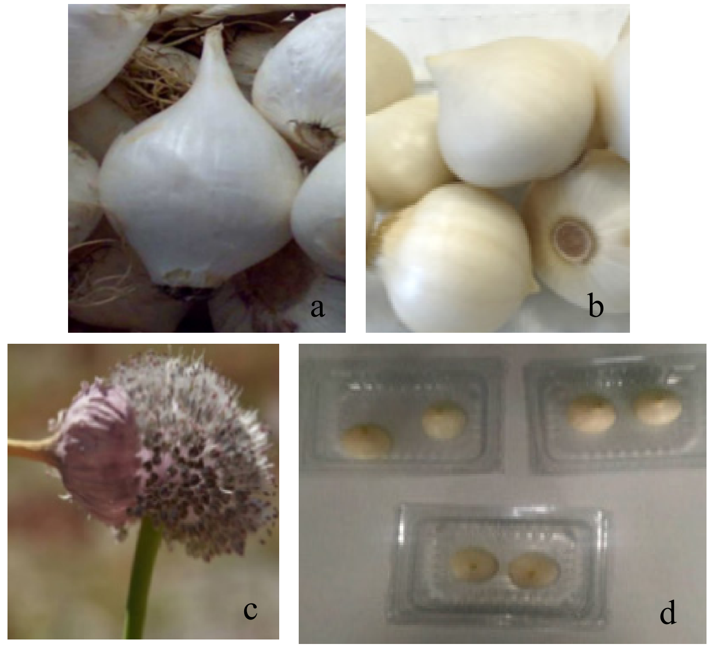

Figure 1. *Allium tuncelianum* collected by local ovacık population in the Tunceli region, Turkey. a. Allium tuncelianum single cloves; b. Allium tuncelianum before packaging; c. Allium tuncelianum in flower; d. MAP package.

Figure 2. Modified atmosphere packaging (MAP) device.

Analysis of the Samples

Degree of sprouting

The method proposed by Meral *et al.* (2024) was applied to garlic samples with modifications. The degree of sprouting was determined by counting the number of spoiled garlic cloves in the sample and calculated as follows.

$$\text{Degree of sprouting} = \frac{\text{Number of sprouted cloves}}{\text{Total number of cloves}} X\ 100 \quad (1)$$

Weight loss

Weight loss was calculated based on the initial weight as:

$$\text{weight loss}\left(g.100\ g^{-1}\right) = \frac{A_1 - A_2}{A_1} \times 100 \quad (2)$$

where is the initial sample weight (g) and is the weight (g) on days 7, 14, 21, and 28.

Dry matter

Dry matter content was determined using moisture determination equipment (Radwag-MA-110R, Poland) within ±1 mg sensitivity. Sample container was loaed with 1 g sample. Samples were dried to constant weight, and the result was reported as percentage dry matter according to method by Sharma and Prasad, (2001).

Water activity

Water activity measurement in garlic samples was done according to the method by Kar and Sutar (2023). The water activity of the sliced samples was determined using a water activity measurement equipment (Novasina Labmaster, Switzerland). Electric resistence range is in between 1 kΩ – 100 MΩ correponding to a water activity range of 0.03-1.00. Thin sliced samples enough to fill the 12 mL sample cell were weighed and loaded into the sample cell. The analysis was performed at 23 ^{o}C.

pH and titratable acidity

pH and titratable acidity measurement with garlic samples was done according to method Nielsen (2010). Garlic samples (5 g) were added to 25 mL distilled water and homogenized (IKA, T8 Ultra-Turrax, Germany), and then the pH at 20 was measured using a pH meter (Thermo Scientific, Orion3Star, Singapore). Titratable acidity was measured by titrating the homogenized solution (10 mL) with 0.1 N NaOH using phenol phytalein indicator (Nielsen, 2010). The titratable acidity was expresed how g citric acid.100 g^{-1}.

Ash content

The ash content of the samples was determined according to the standart international AACC method (AACC. 2000) used by Sajid *et al.* (2014). The ash content was calculated as follows:

$$\text{ash content}\left(\text{g.100 g}^{-1}\right)=\frac{\text{weight of ash (g)}}{\text{Initial weight (g)}}\text{X 100} \qquad (3)$$

Texture profile analysis

For texture profile analysis of the cubic samples (10 × 10 × 10 mm^3) was performed using a texture analyzer (TA-XT PLUS, United Kingdom). Flesh hardness, elasticity, chewiness, and resilience were calculated. The method proposed by He *et al.* (2019) was used with minor modifications. The test were 10×10×10 mm^3 cubic samples. P/36R probe was used during the tests with a test speed of 5 mm.s^{-1}, test duration was 2 s, sample depth of 5 mm and the trigger force was 5 g.

Color

The Hunter Lab values of the samples were measured using a colorimeter (Konica-Minolta CR-400, Japan). It expresses color as three values: L* for perceptual lightness and a* and b* for the four unique colors of human vision: red, green, blue and yellow.

Total phenolic content

Total phenolic content (TPC) was determined spectrophometrically (UV-1601, Shimadzu, Kyoto, Japan) according to the method proposed by Singleton *et al.* (1999), using Folin-Ciocalteu reagent (Benitez *et al.,* 2018). Distilled water was used as the solvent. Gallic acid solutions were used to obtain the standard curve, and the phenolic content was reported in terms of gallic acid equivalents (mg) in a 100 mg sample.

Statistical analysis and experimental design

Samples were prepared in paralel and quality tests were performed in triplicate depending on the number of samples for each group (n=5) and were analyzed statistically. The design with two factors was applied in study. For factor A (control, gas A and gas B), 3 levels were established. For factor B (Day 0, 7, 14, 21 and 28), the levels established correspond to the five different time periods. The technique used for the interpretation of the test statistic is the analysis of the variance (ANOVA). The means of different treatments were compared using Duncan multiple comparison test (SPSS 26.0, New York, U.S.A). Variance analysis and Duncan Test applied to data at a significance level of 0.05 %. Mean values and standart errors are given all tables.

Results and discussion

The control sample exhibited the highest weight and dry matter loss (table 1).

Loss of dry matter is due to the conversion of substrates into via respiration (Guo *et al.,* 2019). Unexpectedly, significant weight loss ($p<0.05$) was observed on day 14 for the control samples. Control samples were expected to lose moisture quickly in the beginning bacause of a high vapor pressure driving force between the garlic surface and the environment, accompanied by a moisture gradient between the surface and inside of the garlic clove. The vapor pressure driving force is expected to decrease as the sample dries, thus causing a decrease in the rate of moisture loss. Therefore, the result on day 14 was probably due to a major change in room conditions owing to a change in atmospheric conditions indicating that uncontrolled room conditions may result in unexpected quality losses. The control samples showed that the major mechanism of weight loss depends on moisture loss in the beginning of storage. Respiration, which causes the loss of dry matter, became dominant after the surface of the control samples dried after day 21 (table 1). Although moisture loss continued throughout 28 days of storage, the water activity of the control did not change significantly ($p>0.05$) during the 28 days' period (table 1).

Both of the initial gas mixtures used in MAP resulted in a decrease in weight loss due to retardation of respiration. In addition, moisture loss was much less than that of the control, depending mainly on the permeability of the polypropylene film. The weight loss and dry matter loss data for gas mixture B were significantly different ($p<0.05$) from those of the control and gas mixture A. Gas mixture B contained more carbon dioxide than gas mixture A (table 1), thus it retarded respiration better than gas mixture A, since both packages were separated from the environment by a polypropylene film that have the same permeability and selectivity against moisture, carbon dioxide, oxygen, and nitrogen. The water activity of the MAP samples increased significantly ($p<0.05$) during the 28 days of storage (table 1).

Moisture formed during respiration, accumulated in the packages due to low moisture permeability of the polypropylene film. The MAP atmosphere became a high relative humidity atmosphere during the storage period. As a result, the samples equilibrated with a high relative humidity packaging atmosphere, which prevented moisture loss from the packaged samples, and thus causing water activity of the samples to increase (He *et al.,* 2019). Dry matter loss for the MAP samples is expected owing to sprouting. No sprouting was observed in the control samples, whereas 87.5 % of MAP treated samples sprouted (table 1) at the end of 28 days of storage. Moderate relative humidity and temperature at room conditions did not promote sprouting whereas high relative humidity in MAP packages caused sprouting inspite of refrigerated storage. Therefore, it was concluded that active MAP with moisture sorption packages should be preferred for MAP preservation of *Allium tuncelianum*. None of the samples experienceda significant change in ash content (table 1), as expected, confirming that weight loss was due to the use of respiration substrates and moisture loss.

Table 1. Change in quality parameters in garlic samples during storage.

Day	Weight loss (%)			Dry matter content (%)		
	C	A	B	C	A	B
0	None	None	None	46.4±0.7^{a,A}	46.4±0.7^{a,A}	46.4±0.7^{a,A}
7	8.2 ± 2.4^{a,A}	3.7±2.5^{a,A}	1,7±0.9^{a,A,B}	47.1±0.6^{b,B}	41.9±0.7^{a,A}	44.9±1.1^{b,A}
14	15.2±4.5^{b,B}	1.0±0.1^{a,A}	2,3±0.3^{a,A,B}	47.8±0.3^{a,B}	43.8±0.7^{b,A,B}	43.5±1.3^{b,A}
21	16.6±9.7^{a,A}	3.6±1.6^{a,A}	3,7±1.2^{a,B}	46.4±1.1^{a,A,B}	44.8±0.7^{a,B,C}	45.6±0.67^{a,A}
28	20.6±12.3^{aA}	3.7±0.4^{a,A}	4,4±0.1^{a,B}	42.3±1.1^{a,A}	45.1±0.7^{b,B,C}	46.0±0.1^{b,A}
Day	**Water activity**			**pH**		
	C	A	B	C	A	B
0	0.8^{a,A}	0.8^{a,A}	0.8^{a,A}	7.1^{a,A}	7.1^{a,A}	7.1^{a,A}
7	0.9^{a,A}	0.9^{a,B}	0.9^{a,B}	6.9^{a,A}	6.7^{a,A}	6.7^{a,A}
14	0.8^{a,A}	0.9^{a,A}	0.9^{a,A}	6.9^{a,A}	6.9^{a,B}	6.9^{a,B,C}
21	0.9^{a,A}	0.9^{b,B}	0.9^{c,B}	6.9^{a,b,A,B}	7.0^{b,B}	6.8^{a,B}
28	0.9^{a,A}	0.9^{a,A,B}	0.9^{a,A,B}	7.0^{a,A,B}	7.1^{a,B}	7.0^{a,C,D}
Day	**Titratable acidity (g citric acid.100 g^{-1})**			**Ash content (g.100g^{-1})**		
	C	A	B	C	A	B
0	0.1^{a,A}	0.1^{a,A}	0.1^{a,A}	1.2^{a,A}	1.2^{a,A}	1.2^{a,A}
7	0.1^{a,A}	0.0^{a,A}	0.1^{a,A}	1.1$^{a, A}$	1.2^{a,A}	1.2$^{a, A}$
14	0.1^{a,A}	0.1^{a,A}	0.1^{a,A}	1.1±0,2^{a,A}	1.2^{a,A}	1.2$^{a, A}$
21	0.1^{a,A}	0.1^{a,A}	0.1^{a,A}	1.0^{a,A}	1.2^{a,A}	1.3±0.1^{a,A}
28	0.1^{a,A}	0.1^{a,A}	1.1^{a,A}	1.0^{a,A}	1.3^{b,A}	1.4^{b,A}
Day	**Total phenolic content (mg gallic acid.100 mg^{-1})**			**Fractional Sprouting**		
	C	A	B	C	A	B
0	175.4±1.9^{a,A}	175.4±1.9^{a,A}	175.4±1.9$^{a, A}$	-	-	-
7	193.6±1.0^{c,B}	134.4±5.9^{b,C}	160.4±3.8$^{a, A}$	0^{a,A}	62.5±53.0^{a,A}	25.0±35.3^{a,A}
14	230.8±2.7^{b,C}	128.5±7.7^{a,B}	120.2±4.6$^{a, A}$	0^{a,A}	37.5±17.6^{a,A}	25.0±35.3^{a,A}
21	258.6±0.7^{c,D}	121.0±4.1^{a,A}	101.8±2.9$^{b, A}$	0^{a,A}	75.0±25.0^{a,A}	62.5±37.5^{a,A}
28	200.5±5.7^{b,B}	163.5±3.4^{b,E}	192.8±2.39^{a,B}	0^{a,A}	87.5±17.6^{a,A}	87.5±17.6^{a,A}

C: Control; A: 5 % O_2, 5 % CO_2, 90 % N_2 gas mixture; B: 3 % O_2, 8 % CO_2, 89 % N_2 gas mixture Lowercase letters denote row-wise differences (p<0.05), uppercase letters denote column-wise differences (p<0.05).

None of the samples showed significant differences (p>0.05) in terms of pH (Table 1) or titratable acidity (Table 1), indicating no formation of organic acids due to enzymatic or microbiological activity. The TPC of the control and MAP samples increased significantly (p<0.05) during the storage period (Table 1). TPC is known to increase upon sprouting and / or tendency to sprout (Martins *et al.,* 2016; Takim, 2020).

All samples retained their texture properties, with gas mixture B showing the highest consistency (Table 2).

Its higher CO_2 content reduced weight loss and slowed respiration (Table 1), improving texture, as noted in previous studies (Liu *et al*., 2021; Singh *et al*., 2019).

Original color values (L*=80; a*=-1.9; b*=12) remained stable for 28 days under both room and MAP conditions. Thus, gas mixture B with MAP and moisture-absorbent pouches effectively preserves *Allium tuncelianum* freshness for up to 28 days.

Conclusions

Allium tuncelianum is an important endemic plant source with economic importance to the local population, and important healthy properties characteristic of the Tunceli regional cuisine with a less tangy flavor that can extend its gastronomic utilization in a wider geography including fresh consumption in salads and fermented

Table 2. Results of texture profile analysis (TPA).

T.P*		Day 0	Day 7	Day 14	Day 21	Day 28
H*	C	5666.64±453.17^{a,A}	4296.58±633.55^{a,A,B}	5273.34±1034.23^{a,A,B}	4695.79±428.17^{a,A,B}	3566.73±183.88^{a,A}
	Gas A	5666.64±453.17^{a,A,A}	5275.68±502.3^{a,A,B,C}	6449.92±558.75^{a,C}	4249.10±637.40^{a,A,B}	3333.13±528.61^{a,A}
	Gas B	5666.64±453.17^{a,A}	5889.55±1135.96^{a,A}	4898.14±417.03^{a,A}	4162.26±478.05^{a,A}	5627.57±361.11^{b,A}
E*	C	0.74±0.01^{a,A}	0.73±0.06^{a,A}	0.76±0.03^{a,A}	0.75±0.01^{a,A}	0.71±0.03^{a,A}
	Gas A	0.74±0.01^{a,A}	0.71±0.08^{a,A}	0.75±0.00^{a,A}	2.08±1.37^{a,A}	0.78±0.01^{b,A}
	Gas B	0.74±0.01^{a,A,B}	0.81±0.04^{a,B}	0.73±0.01^{a,A}	0.76±0.01^{a,AB}	0.77±0.05^{b,AB}
C*	C	2543.01±274.86^{a,A}	2003.51±198.92^{a,A}	2680.97±430.90^{a,A}	2485.14±315.58^{a,A}	1753.94±92.36^{a,A}
	Gas A	2543.01±274.86^{a,A}	2531.38±270.05^{a,A}	3107.60±295.63^{a,A}	3891.77±11657.48^{a,A}	1815.00±248.75^{a,A}
	Gas B	2543.01±274.86^{a,A}	3147.58±613.94^{a,A}	2321.74±189.98^{a,A}	2412.54±228.43^{a,A}	3130.31±232.76^{b,A}
R*	C	0.44±0.03^{a,A}	0.52±0.03^{a,A}	0.53±0.01^{a,A}	0.55±0.04^{a,A}	0.55±0.03^{a,A}
	Gas A	0.44±0.03^{a,A}	0.57±0.05^{a,B}	0.49±0.01^{a,A,B}	0.55±0.03^{a,A,B}	0.54±0.02^{a,A,B}
	Gas B	0.44±0.03^{a,A}	0.52±0.01^{a,A,B}	0.50±0.02^{a,A,B}	0.64±0.02^{a,C}	0.55±0.01^{a,B,C}

T.P*: Texture Profile, H: Hardness, E: Elasticity, C: Chewiness, R: Resilience C: Control; A: 5 % O_2, 5 % CO_2, 90 % N_2 gas mixture; B: 3 % O_2, 8 % CO_2, 89 % N_2 gas mixture. Lowercase letters denote row-wise differences ($p<0.05$), uppercase letters denote column-wise differences ($p<0.05$).

products. Minimally processed storage of *Allium tuncelianum* upon active MAP with an initial gas composition of 3 % O_2, 8 % CO_2 and 89 % N_2 has the potential to add value to this endemic plant by presenting it to a wider geography. Water adsorbant pouches must be placed in the packages to prevent sprouting.

Funding

The present study was funded by project YLMUB019-09, Munzur University Tunceli, Turkey.

Literature cited

AACC. 2000. Approved methods of the American Association of Cereal Chemists, 10th Ed. AACC, St. Paul, MN, USA

Bansal, V., Siddiqui, M.W., & Rahman, M.S. (2015). Minimally Processed Foods: Overview. In: Siddiqui, M., Rahman, M. (eds) Minimally Processed Foods. Food Engineering Series. Springer, Cham. https://doi.org/10.1007/978-3-319-10677-9_1

Benitez, V., Esteban, R. M., Moniz, E., Casado, N., Aguilera, Y., & Mollá, E. (2018). Breads fortified with wholegrain cereals and seeds as source of antioxidantdietary fibre and other bioactive compounds. *Journal of Cereal Science, 82*, 113-120. https://doi.org/10.1016/j.jcs.2018.06.001

Cantwell, M.I., Hong, G., Kang, J., & Nie, X. (2003). Controlled atmospheres retard sprout growth affect compositional changes and maintain visual quality attributes of garlic. *Acta Horticulturae, 600*, 791-794. https://doi: 10.17660/ActaHortic.2003.600.122

Chaix, E., Couvert, O., Guillaume, C., Gontard, N., & Guillard, V. (2015). Predictive microbiology coupled with gas (O_2/CO_2) transfer in food/packaging systems: how to develop an efficient decision support tool for food packaging dimensioning. *Comprehensive Reviews in Food Science and Food Safety, 14*(1), 1-21. https://doi.org/10.1111/1541-4337.12117

Chen, J., Hu, Y., Yan, R., Hu, H., Chen, Y., & Zhang, N. (2019). Modeling the dynamic changes in O_2 and CO_2 concentrations in MAP packaged fresh-cut garlic scape. *Food Packaging and Shelf Life, 22*, 100432. https://doi.org/10.1016/j.fpsl.2019.100432

Çam, O., & Çelik, C. (2024). Sarımsak: Gastronomi ve Sağlık Açısından Değerlendirmeler. *Akra Kültür Sanat Ve Edebiyat Dergisi, 12*(32), 135-150. https://doi.org/10.31126/akrajournal.1191485

Davies, A.R., (1999). Advances in Modified-Atmosphere Packaging. In G.W. Gould (Ed.). Aspen Publishers, Gaithersburg, U.S.A. pp. 304-320.

Dronachari, M., Venkatachalapathy, K., & Rajashekarappa, K. S. (2010). Effect of pretreatments and packaging on shelf-life of peeled garlic cloves. *Journal of Dairying, Foods and Home Sciences, 29*(2), 130-135. Print ISSN: 0971-4456 https://arccarticles.s3.amazonaws.com/webArticle/articles/jdfhs292011.pdf

EL-Mesery, H. S., Sarpong, F., Xu, W., & Elabd, M. A. (2022). Design of low-energy consumption hybrid dryer: A case study of garlic (*Allium sativum*) drying process. *Case Studies in Thermal Engineering, 33*, 101929. https://doi.org/10.1016/j.csite.2022.101929

El-Saadony, M. T., Saad, A. M., Korma, S. A., Salem, H. M., El-Mageed, A., Taia, A., & Ibrahim, S. A. (2024). Garlic bioactive substances and their therapeutic applications for improving human health: A comprehensive review. *Frontiers in immunology, 15*, 1277074. https://doi.org/10.3389/fimmu.2024.1277074

Ezeorba, T. P. C., Ezugwu, A. L., Chukwuma, I. F., Anaduaka, E. G., & Udenigwe, C. C. (2024). Health-promoting properties of bioactive proteins and peptides of garlic (*Allium sativum*). *Food Chemistry, 435*, 137632. https://doi.org/10.1016/j.foodchem.2023.137632

González-Buesa, J., Ferrer-Mairal, A., Oria, R., & Salvador, M. L. (2009). A mathematical model for packaging with microperforated films of fresh-cut fruits and vegetables. *Journal of Food Engineering, 95*, 158–165. https:// doi:10.1016/j.jfoodeng.2009.04.025

Guo, Z., Liu, H., Chen, X., Huang, L., Fan, J., Zhou, J., & Chang, X. (2019). Modified-atmosphere packaging maintains the quality of postharvest whole lettuce (*Lactuca sativa* L. Grand Rapid) by mediating the dynamic equilibrium of the electron transport chain and protecting mitochondrial structure and function. *Postharvest Biology and Technology, 147*, 206-213. https://doi.org/10.1016/j.postharvbio.2018.09.001

He, Y., Fan, G. J., Wu, C. E., Kou, X., Li, T. T., Tian, F., & Gong, H. (2019). Influence of packaging materials on postharvest physiology and texture of garlic cloves during refrigeration storage. *Food Chemistry, 298*, 125019. https://doi.org/10.1016/j.foodchem.2019.125019

Hirschegger, P., Jakše, J., Trontelj, P., & Bohanec, B. (2010). Origins of *Allium ampeloprasum* horticultural groups and a molecular phylogeny of the section Allium (*Allium: Alliaceae*). *Molecular Phylogenetics and Evolution, 54*, 488-497. https://doi: 10.1016/j.ympev.2009.08.030

Ishangulyyev, R., Kim, S., & Lee, S. H. (2019). Understanding food loss and waste why are we losing and wasting food? *Foods, 8* (8), 297. https://doi.org/10.3390/foods8080297

Kang, J, and Lee S., (1999). Modified atmospherepackaging of peeled garlic cloves. *Food Science and Biotechnology, 8 (1)*, 68-71. https://www.researchgate.net/publication/272482197_Modified_atmosphere_packaging_of_peeled_garlic_cloves

Kar, S, and Sutar, P. P. (2023). Shelf life prediction of dried garlic powder under accelerated storage conditions. *Journal of Food Science and Technology, 60* (3), 996-1005. https://doi.org/10.1007/s13197-022-05431-2

Kargwal, R., Garg, M. K., Singh, V. K., Garg, R., & Kumar, N. (2020). Principles of modified atmosphere packaging for shelf life extension of fruits and vegetables: An overview of storage conditions. *International Journal Chemical Studies, 8* (3), 2245-2252. https://doi.org/10.22271/chemi.2020.v8.i3af.9545

Li, X., Li, L., Wang, X., & Zhang, L. (2010). Notice of Retraction: Improved keeping quality of fresh-cut garlic sprouts by atmosphere packaging conditions. In 2010 The 2nd Conference on *Environmental Science and Information Application Technology* (Vol. 3, pp. 317-320). IEEE. 10.1109/ESIAT.2010.5568327. https://ieeexplore.ieee.org/document/5568327

Liu, H., Xu, L., Yu, F., Tan, J., Cao, L., Xing, Y., & Che, Z. (2021). Effects of different ozone treatments on the storage quality and stability of fresh peeled garlic. *RSC Advances, 11* (37), 22530-22543. https://doi.org/10.1039/D1RA00433F

Martins, N., Petropoulos, S., & Ferreira, I. C. (2016). Chemical composition and bioactive compounds of garlic (*Allium sativum* L.) as affected by pre-and post-harvest conditions: A review. *Food Chemistry, 211*, 41-50. https://doi.org/10.1016/j.foodchem.2016.05.029

Meral, N., Şen, F., & Yılmaz, E. (2024). Determination of the Effects of Modified Atmosphere Packaging and 1-Methylcyclopropene Applications on the Storability of 'Farfia' Apricot Fruits. *Turkish Journal of Agriculture-Food Science and Technology, 12*(s1), 2060-2068. https://doi.org/10.24925/turjaf.v12is1.2060-2068.7034

Mondal, A., Banerjee, S., Bose, S., Mazumder, S., Haber, R. A., Farzaei, M. H., & Bishayee, A. (2022). Garlic constituents for cancer prevention and therapy: From phytochemistry to novel formulations. *Pharmacological Research, 175*, 105837. https://doi.org/10.1016/j.phrs.2021.105837

Nielsen, S. S., (2010). Food Analysis Textbook. 4.th. edition. Springer Verlag. Germany. https://doi 10.1007/978-1-4419-1478-1

Pedisić, S., Zorić, Z., Miljanović, A., Šimić, D., Repajić, M., & Dragović-Uzelac, V. (2018). Retention of bioactive compounds during domestic processing of croatian domestic garlic (*Allium sativum* L.). *Food Technology and Biotechnology* 56(4), 590-596 https://doi: 10.17113/ftb.56.04.18.5709

Phillips, C.A. (1996). Review: Modified Atmosphere Packaging and Its Effects on the Microbiological Quality and Safety of Produce. International. *Journal Food Science Techology, 31*, 463-479. https://doi:10.1046/j.1365-2621.1996.00369.x

Rashvand, M., Matera, A., Altieri, G., Genovese, F., Nikzadfar, M., Feyissa, A. H., & Di Renzo, G. C. (2024). Effect of dielectric barrier discharge cold plasma on the bio-nanocomposite film and its potential to preserve the quality of strawberry under modified atmosphere packaging. *Food and Bioprocess Technology, 17*(5), 1247-1264. https://doi.org/10.1007/s11947-023-03196-w

Sajid, M., Butt, M. S., Shehzad, A., & Saira Tanweer, S. T. (2014). Chemical and mineral analysis of garlic: a golden herb. *Pakistan Journal of Food Science. 24* (2): 108-110.https://www.researchgate.net/publication/304284739_Chemical_and_mineral_analysis_of_garlic_a_golden_herb

Sandhya, K. V. K. (2010). Modified atmosphere packaging of fresh produce: Current status and future needs. *LWT- Food Science and Technology. 43*, 381–392. https://doi.org/10.1016/j.lwt.2009.05.018

Shagun, S., Bains, A., Sridhar, K., Dhull, S. B., Patil, S., Gupta, V. K., & Sharma, M. (2024). A comprehensive review on impact of post-harvest management and treatment practices on the quality of garlic (*Allium sativum* L) during storage. *Scientia Horticulturae*, 337, 113586. https://doi.org/10.1016/j.scienta.2024.113586

Sharma, G. P., and Prasad, S. (2001). Drying of garlic (*Allium sativum*) cloves by microwave–hot air combination. *Journal of Food Engineering, 50* (2), 99-105. https://doi.org/10.1016/S0260-8774(00)00200-4

Singh, S., Gaikwad, K. K., & Lee, Y. S. (2019). Development and application of a pyrogallic acid-based oxygen scavenging packaging system for shelf life extension of peeled garlic. *Scientia Horticulturae, 256*, 108548. https://doi.org/10.1016/j.scienta.2019.108548

Singleton, V.L., Orthofer, R., & Lamuela-Raventos, R.M., (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology, 299*, 152-178. https://doi.org/10.1016/s0076-6879(99)99017-1

Sivertsvik, M., Jeksrud W.K., & Rosnes, J. T. (2002). A review of modified atmosphere packaging of fish and fishery products – significance of microbial growth, activities and safety. *International Journal of Food Science and Technology, 37*, 107-127 https://doi.org/10.1046/j1365-2621.2002.00548.x

Takim, K. (2020). Tunceli dağ sarımsağı (*Allium tuncelianum*) farklı eksraksiyonlarında LC-MS/MS ile fenolik bileşik miktarlarının karşılaştırılması. *Harran Tarım Ve Gıda Bilimleri Dergisi, 24*(1), 44-52. https://doi.org/10.29050/harranziraat.591171

Thakur, P., Dhiman, A., Kumar, S., & Suhag, R. (2024). Garlic (*Allium sativum L.*): A review on bio-functionality, allicin's potency and drying methodologies. *South African Journal of Botany*, 171, 129-146. https://doi.org/10.1016/j.sajb.2024.05.039

Vázquez-Barrios, M. E., Lopez-Echevarría, G., Mercado-Silva, E., Castano-Tostado, E., & Leon-Gonzalez, F. (2006). Study and prediction of quality changes in garlic cv. Perla (*Allium sativum L.*) stored at different temperatures. *Scientia Horticulturae, 108*, 127–132. https://doi.org/10.1016/j.scienta.2006.01.013.

Venu Madhav, J., Sethi, S., Kaur, C., & Pal, R. K. (2016). Quality evaluation of modified atmosphere packed minimally processed garlic cloves. *Indian Journal of Horticulture, 73*, 274–278. https://doi.org/10.5958/0974-0112.2016.00060.8

Wani, A. A., Singh, P., Pant, A., & Langowski, H. C. (2015). Packaging Methods for Minimally Processed Foods. M. W. Siddiqui, M. S. Rahman (Eds.). Springer International Publishing, U. S. A. pp. 35–55. https://doi: 10.1007/978-3-319-10677-9_3

Ward, G. (2016). Modified atmosphere packaging for extending storage life of fresh fruits and vegetables. *Reference Module in Food Science*. https://doi.org/10.1016/B978-0-08-100596-5.03167-X

Yumrutaş, Ö., Demirörs, S. S., & Doğan, M., (2009). The in vitro antioxidant activity of *Allium tuncelianum*: An endemic. *Journal of Applied Biological Sciences, 3*, 3, 61-64. https://dergipark.org.tr/tr/download/article-file/415359